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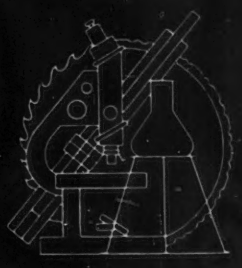
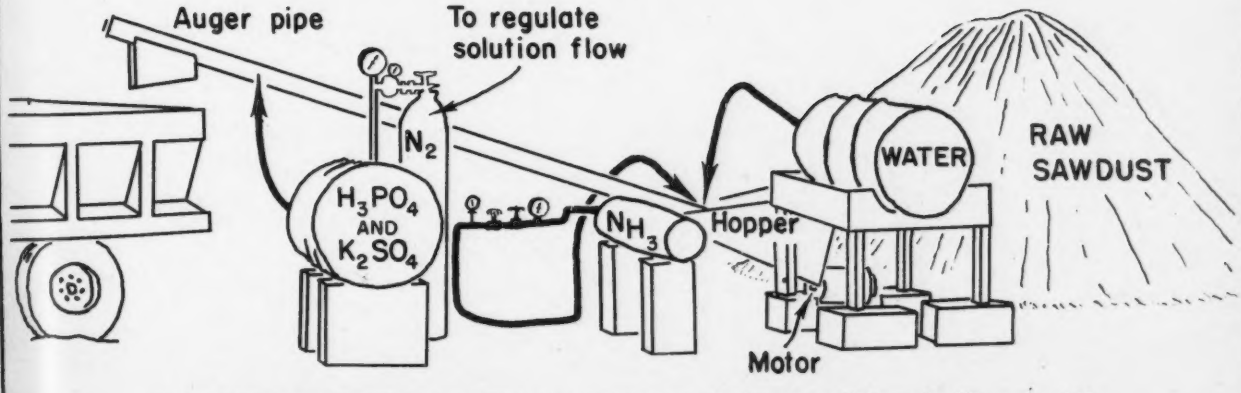
Forest Products Journal





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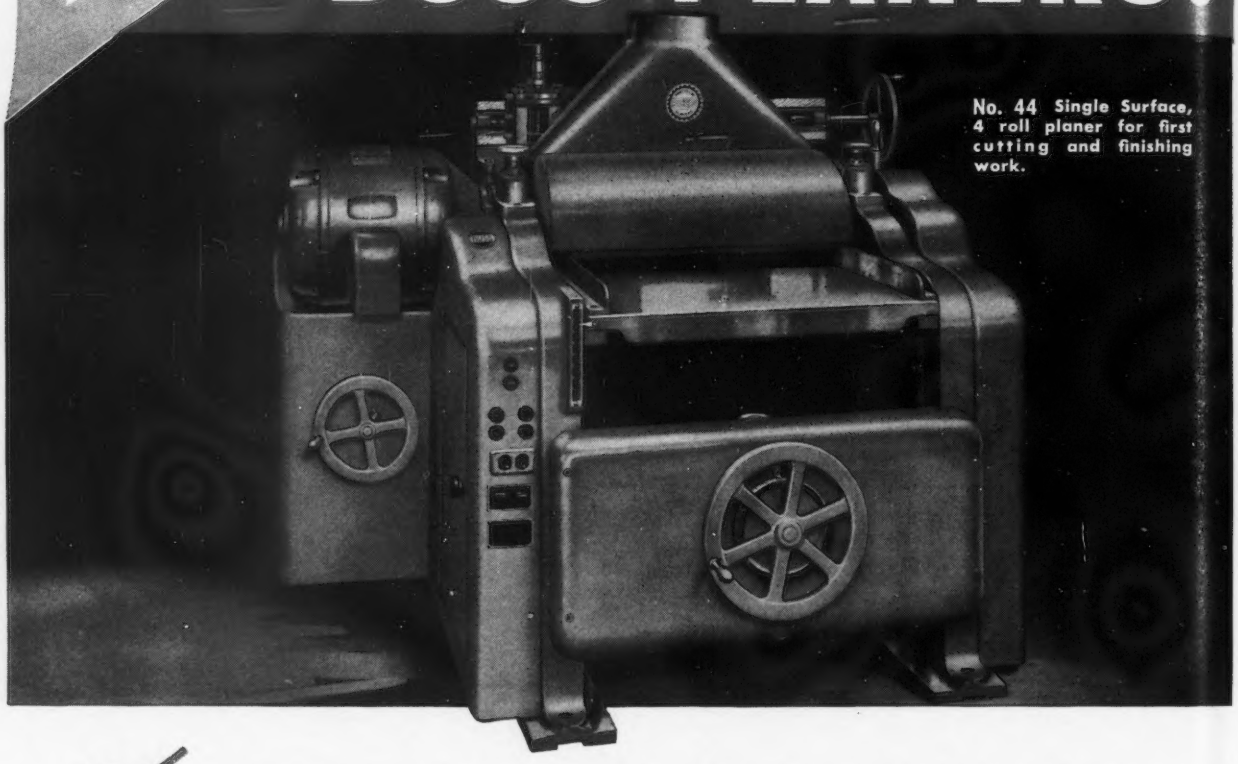

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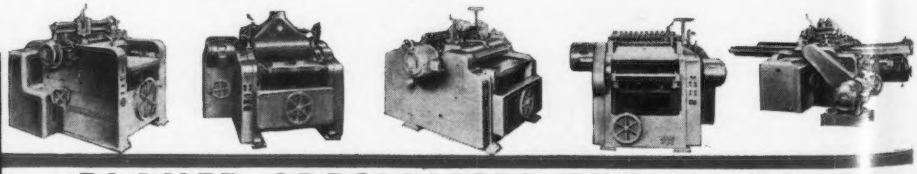

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Feb. 1959: Rocky Mountain Section Meeting, Ft. Collins, Colo.

Feb. 2–3, 1959: Pacific Northwest Section Meeting, Coos Bay, Ore.

May 21–22, 1959: Joint Eastern Canadian—Northeast Spring Section Meeting, Ottawa, Ontario.

June 28–July 3, 1959: Thirteenth National Meeting, San Francisco, Calif.

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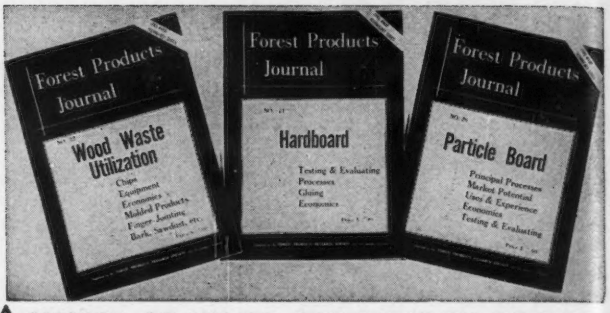

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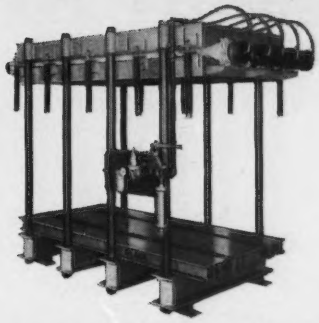

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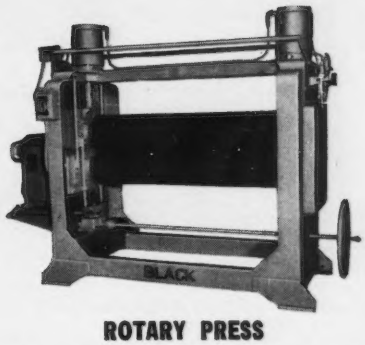

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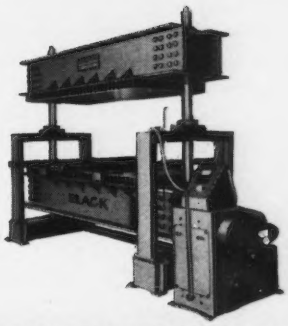

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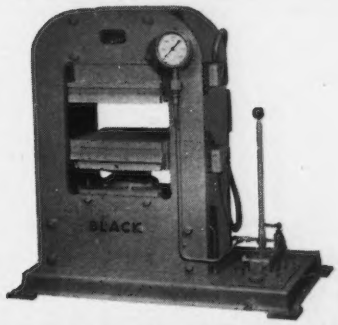

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FPRS NEWS-DIGEST

Volume VIII NOVEMBER, 1958 Number 11

New AIWE, FPRS Budget, Subjects at Board Meet

DURING THE 2-day shirt-sleeve session, the Executive Board posed for an informal photo. Shown l. to r. are R. H. Berry, J. J. Allegretti, Tony Veazey, Jr., Fred Dickinson, W. R. Warner, W. L. Irwin, F. H. Kaufert, E. S. Harrar, President Eason, and D. K. Saunders.

AT THE EXECUTIVE Board Luncheon were l. to r. W. R. Warner, Southern Lbr. Co., a guest; F. X. Gigliotti, Monsanto Chemical Co., a guest; R. D. Pauley, Weyerhaeuser Timber Co., a past president of the Society, and President Eason, Nickey Bros.

CHICAGO, Nov. 7—A basis for developing closer cooperation between the American Institute of Wood Engineering (AIWE) was an important item of business at the FPRS Executive Board Meeting held here at the Sheraton–Blackstone Hotel, according to Executive Secretary F. J. Rovsek.

Representatives of AIWE met with the 11-member Executive Board to propose a program of close cooperation between the two organizations

The Institute was first organized in June of 1958 and now has more than 100 members, virtually all of whom are members of FPRS. Representatives of AIWE who presented the proposals were: Dr. James S. Bethel, N. C. State College, the Institute's president; Dr. H. O. Fleischer, USFPL; Dr. Alex Panshin, Mich. State U.; and Mr. A. Muschler, Edward Hines Lbr. Co., Chicago.

In explaining the objectives of the organization, Bethel stressed to the FPRS Executive Board that the AIWE in no way wished to compete with FPRS and that the membership had specifically expressed the desire that its officers seek means of close cooperation with FPRS.

In other action, the Board reached a valuation of $70,000 for the Executive Office Building in Madison, and has announced that it will be completely paid for by the end of this fiscal year.

It was decided that with the members' dues invoicing on or about Dec. 1, all members of the Society will be asked to re-confirm or otherwise indicate their affiliation with individual Divisions of the Society. An operating budget of about $94,000 income and expenditure was also approved for 1959.

R. H. Berry, General Chairman of the 1959 National Meeting Committee, reported that a light apparatus and suppliers' tabletop exhibit will be held at the meeting. The purpose, he said, will be to give the supplying segment of the Society an opportunity to display its products and services to its customers and prospects. The exhibit is expected to number about 100 displays.

The Board voted to hold a meeting in Madison during January, 1959, to consider long-range membership interests and ways to attract more persons from the management end of the wood industry to the Society.

ALSO PRESENT were l. to r. J. J. Allegretti, Masonite Corp.; R. L. Hiller, American Cyanamid; W. L. Irwin, Poinsett Lbr. & Mfg. Co.; and A. J. Panshin, Michigan State U. Mr. Panshin attended as a representative of AIWE.

OTHERS WHO ATTENDED were l. to r. A. Muschler, Edward Hines Lbr. Co.; H. O. Fleischer, USFPL; D. K. Saunders, Saunders Bros. Inc.; Fred Dickinson, Calif. Forest Products Lab.; and James Bethel, N. C. State College. Muschler, Fleischer, and Bethel represented AIWE.

Many Themes Discussed at Fall Section Meetings

GREAT LAKES SECTION. Featured guests at the Houghton, Mich. meeting held Aug. 21–22 were (seated l. to r.): G. R. Petrie, U. S. Dept. of Commerce; Fred Atkinson, Section Chrm.; and S. D. Horner, Horner Flooring Co. Standing are: D. J. Massoglia, Timber Producers Assoc.; Rev. William McGee; and Brooks Applegate, Travis–Applegate Co.

THEME OF THE MEETING was Entrepreneuring of Forest Products in the Lake States. More than 60 persons attended. Members of the local arrangements committee were (seated l. to r.): J. F. Hamilton, Hereford Garland, Chrm. of the Committee; and Walter Koepp. Standing are C. S. Danielson, Jr., and Donald J. Yeadon. All are with the Mich. College of Mining & Technology.

INLAND EMPIRE SECTION. At the head table during the Official Banquet were (l. to r.): J. P. Howe, U. of Idaho, Section Sec.; Nels Sandberg, Waldorf Paper Products; Ross McNett, Biles–Coleman Lbr. Co., Section Chrm.; Charles Kreider, Brooks Scanlon, Inc., Section Vice-Chrm.; and H. H. Koessler, Intermountain Lbr. Co.

ATTENDANCE AT THE meeting, held Sept. 25–27 at Missoula, Mont., reached 103, exclusive of women. This represents 86 per cent of the Section membership. The meeting consisted entirely of plant tours, with speakers outlining points of interest before each tour.

MID SOUTH SECTION. Some of the registrants at the meeting held Oct. 12–14, at LSU, Baton Rouge. Center back row is new Chrm., Tom Orth, Kirby Lbr. Co.

FEATURED SPEAKERS were (l. to r.): Devere Dierks, Jr., Dierks Forests, Inc.; Latane Temple, Southern Pine Lbr. Co.; W. C. Hopkins, LSU; and meeting Chrm., Mark Lehrbas.

OFFICERS OF THE SECTION are shown during their annual business meeting held at the School of Forestry, LSU. Total attendance for the 2-day meeting numbered about 40 registrants.

OHIO VALLEY SECTION. Speakers were (l. to r.): Stanley Suddarth, Purdue U.; J. R. Kersher, Serge A. Birn Co.; and T. C. Weill, General Electric Co.

PAST AND PRESENT Section Officers. Fourth from left is Sterling Durst, Gamble Bros. Inc., new Chrm., and on his right, Paul Fenn, Tell City Chair Co., past Chrm.

REGISTRANTS WIVES who participated in the Womens Program. Indian summer weather graced the meeting to the added enjoyment of all.

THE CORNWELL CO., manufacturers of TV cabinets, were visited during the meeting. Part of the group who participated is shown.

THE LUNCHEON at the two-day meeting, held in French Lick, Ind., was addressed by Carl Seng, past Chrm. of the Section.

SOME OF THE more than 40 registrants that attended the meeting. Planned primarily as a practical workshop clinic, the sessions attempted to answer specific questions raised by industry.

MID-WEST SECTION. At the meeting in St. Louis, Nov. 3–4 were: FPRS President Eason; (standing) Section Chrm. Bensend, and Robert Archambeault, new Vice-chrm. Seated are H. J. Gill and Ira Hatfield.

OTHER SPEAKERS were (l. to r.) J. J. Allegretti, Masonite Corp.; O. C. Lance, Nat'l Woodwork Mfrs. Assoc.; C. Miles Burpee, American Wood Preservers Institute; and R. Archambeault, National Casein Co.

DONALD A. KULP (center), Casswood Industries Inc., spoke on how pressure treating can expand the use of various species. Left is G. B. Hartman, Iowa State College, and right, H. J. Gill.

DON LAUGHNAN, USFPL (l.), answered questions during the Name Your Problem question-answer session after his talk on comparing different methods of evaluating water repellency of treated wood.

OTHER MODERATORS, Speakers and arrangements chairmen were (l. to r.): H. J. Gill, R. V. Weyland, Monsanto Chemical Co., and Ira Hatfield. Seated are: Wayne Bradley, Corps. of Engrs., and W. J. Butler, Dierks Forests Inc.

AT THE BUSINESS meeting were (l. to r.): Ira Hatfield, Wood Treating Chemicals Co.; Jack Koellisch, *Wood and Wood Products*; D. W. Bensend, Iowa State College; R. Archambeault, Vice-chrm. elect; and J. H. Gill, Caradco.

Ottawa Site of Joint Spring Meeting of Eastern Canadian and Northeast Sections

A tour of the Ottawa Forest Products Laboratory will be featured at a joint meeting of the Eastern Canadian and Northeast Sections, May 25 and 26, 1959, Section officials report. Headquarters hotel will be the Chateau Laureir.

Three technical sessions, with five papers to be arranged by each Section, and a banquet are planned. The meeting will coincide with the Ottawa Tulip Festival. A women's program will include a bus tour of Ottawa and a boat trip of city waterways.

Lake States Potential Theme of Great Lakes Aug. Meeting

The economic potential of the Upper Lake States region in relation to forest products was explored at the Great Lakes Section meeting, Aug. 21–22, at Houghton, Mich., Section officers reported. Headquarters were at Michigan College of Mining & Technology.

One of the featured speakers was FPRS President Eason, who spoke to the more than 50 registrants on the need of the Society to attract more members from management.

The forest resources of the region have declined from an estimated 100 million acres of virgin timber to some 50 million acres, of which 15 million are on a non-productive level, A. W. Toole, Lake States For. Exp. Sta., stated at Session I. There is still, however, a vast untapped potential, he stressed. Another speaker at the session indicated that hard maple, yellow birch, aspen, basswood and hemlock were the principle species available.

In discussing the Upper Peninsula, G. L. Johnson, Upper Peninsula Economic Development Group, pointed out that it was one of the few remaining undeveloped areas close to marketing centers. Within a 500-mile radius, he said, are some 50 million consumers.

Wood product diversification was discussed by Richard Connor, Connor Lumber and Land Co. He reported that his firm had cut logging from 30,000,000 to five million board feet, but maintained sales volume through end-product diversification.

A successful furniture operation located in the Upper Peninsula was described by Edward Khoury, Khoury Bros. Millworks, Inc. In 1946 when the firm was formed it used 15 thousand board feet of lumber, compared to two million board feet today.

Featured Plant Tours Attract 103 to Inland Empire Meeting

Reconsideration of Douglas-fir strength and stiffness values were urged at the Inland Empire Section meeting, Sept. 25, 26, and 27, at Missoula, Montana. Attendance at the semi-annual event, exclusive of wives, reached 103, equal to 86 per cent of the membership.

Registrants represented 30 firms engaged in lumber production and processing. If the tonnage of pres-to-logs and of pulp and paper produced by these firms were added to the lumber volume, the companies represented at the meeting would account for an annual sales volume of about 225 million dollars, John P. Howe, Section secretary, reported.

The meeting consisted entirely of plant tours. Special features of the plants were reviewed at scheduled luncheons and dinners before the tours. Visited were Mission Homes, a prefab home manufacturer; Rother Lumber Co.; Elk Horn Lumber Co.; Lumber Division, Anaconda Copper Co.; Intermountain Lumber Co.; and the Waldorf Pulp mill.

During the course of the meeting, a description of the work by representatives of the mills in the Western Pine Assoc. towards obtaining equal stress values for Douglas-fir were presented. As a result, the resolution below was unanimously approved.

"Because of the very serious harmful effects to the lumber industry of the Inland Empire resulting from the continued difference in stress values between Inland and Coast Douglas-fir and in view of the impracticability of segregating Douglas-fir from various regions when it leaves its area of growth and in light of procedures of arriving at design values for other species, the Inland Empire Section of FPRS assembled at its semi-annual meeting at Missoula, Montana on September 25, 26, and 27, 1958, urges the U. S. Forest Products Laboratory and the Committee D7 of ASTM to carefully reconsider its position on Douglas-fir and adopt equal stresses for Douglas-fir grown in the several regions".

Special features observed on the tours were: two Glu-Lam beam fabricating operations, 4 barker installations, horizontal and vertical chippers of several types; horizontal and vertical resaws; a new finger-jointing operation; and a high speed 86 inch diameter log bucking saw.

Thirteen voting and one supporting membership, were signed up by the Section during the meeting. National Society President Eason and Northwest Regional Board Member Veazey participated in the meeting. Program chairman for the meeting was Cam Warren.

Mid-South Section Held October Meeting at LSU

Topics from increased use of lumber products for construction to utilization of low-grade residues were discussed at the Mid-South Section Meeting, Oct. 12–14, at Baton Rouge, La. Headquarters was the School of Forestry at Louisiana State University.

"Wood in the Public Schools" was the topic of a paper presented by Latane Temple, Southern Pine Lumber Co. The lumber industry is laggard in investing money to influence the architect, while the metals and ceramics industries continually propagandize architects and builders with the favorable aspects of their products, he said.

Current technology for flake board application was discussed by Dan Copp, United Wood Corp. He pointed out the low cost of flake board, about $160 per thousand square feet for ¾ inch board, compared with lumber core, which costs in the range of $240 to $320, and softwood plywood at $210.

Both FPRS President W. Jeter Eason and Executive Secretary F. J. Rovsek addressed the Official Luncheon. Mr. Eason pointed out, as he had at other Section meetings this fall, the need for attracting more management personnel to the Society to ensure future growth of the organization.

The status of forest products research, past and present, was the topic of Secretary Rovsek's talk. In pointing out the importance of research to the industry, he stated that one-half to three-fourths of the products now manufactured by some of America's largest concerns were unknown or in the research stage 10 or 15 years ago. In the future of the wood industry it will be imperative that greater emphasis be placed upon fundamental research. Present over-emphasis on applied research can jeopardize our potential for further achievement by depleting the stockpile of existing knowledge, he stated.

Other topics discussed during the 3-day meeting were: the proper use of paneling; marketing of lumber treated with a toxic, water-repellent preservative; hardwood logging and utilization; hardwoods for pulp; and the marketing of particle board.

Officers elected were: Tom Orth, Kirby Lumber Co., Chairman; Donald McCrite, Nickey Bros., Vice-Chairman; and Paul Kramer, Texas Forest Service, Secretary-Treasurer.

Wood Preservation Was Theme of Nov. Mid-West Meeting

"Preservation of Forest Products as a means of Preserving Wood Markets" was the theme of the Mid-West Section meeting, Nov. 3–4, in St. Louis, Mo. Headquarters was the Holiday Inn Hotel.

Housing provides the largest potential market for wood preservatives, C. Miles Burpee, American Wood Preservers Institute, said in a talk on treated woods and competitive materials. He reviewed some of the advancements made by the industry in recent years.

J. J. Allegretti, North Central Regional Board member, stressed that the industry must create a demand for preservative-treated wood at the lending agency, the FHA, the VA, and so forth. The cost of treating a new house for termite and decay prevention in the South ranges from $300 to $500, compared to about $118 in the North for minimum protection, he said.

The results of a series of tests on 11 different combinations of repellents and preservatives were described by D. L. Laughnan, USFPL. A Name Your Problem discussion followed Mr. Laughnan's talk.

FPRS President Eason addressed the registrants at the Official Luncheon. Other topics discussed at the meeting were: how colleges and universities can promote interest in wood preservation; how pressure treating can extend the use of various species; preservative treatment of ponderosa pine millwork by the vacuum process; wood preservation thinking must extend beyond poles, piles, and ties; and water-repellent preservative treatment as seen from the military procurement standpoint.

Officers elected were: W. A. Kluender, Chicago & NW Railway System, Chairman; Robert Archambeault, National Casein Co., Vice-Chairman; J. R. Roberts, The Celotex Corp., Secretary; and Kenneth Kimball, USFPL, Treasurer.

Lumber and Plywood Grading Theme of Pacific Southwest Meeting Held in Los Angeles

Lumber and Plywood Grading was the theme of the Pacific Southwest Section Meeting, held Sept. 17 in Los Angeles, Ole Anderson, Section Secretary, reported.

Main speakers were D. P. Comstock, Western Pine Assoc., Dick Anderson, Douglas Fir Plywood Assoc.; and George Sullivan, a past National Hardwood Assoc. grader now with E. J. Stanton & Son Inc.

Glued Wood Products Subject of Florida–Georgia–Alabama Meeting, Dec. 4–5, in Mobile

"Glued Wood Products" was the theme of the Florida-Georgia-Alabama annual fall meeting, Dec. 4 and 5 at Mobile, Ala. Headquarters hotel was the Battle House.

Subjects discussed were: specifications for and grading of glued lumber products; economic problems connected with the production of glued products; production of laminated framing members and sheathing; end jointing; economic aspects of flake and particle board manufacture; particle or flake manufacture and its relation to board quality; and binders for boards.

Question and Answer Sessions Basis of Ohio Valley Meeting

With a program organized on a question and answer basis, the Ohio Valley Section held a productive meeting, Oct. 16–17, at French Lick Spa, in southern Indiana.

First speaker, S. K. Suddarth, Purdue U., pointed out that some of the simplified tests used to determine the strength of glued and nailed constructions might be applied to test furniture products. The audience, composed largely of furniture and woodworking people, indicated that Purdue should be encouraged to conduct this type of research with emphasis on the field of improved glued furniture joints.

J. R. Kershner, Serge A. Birn Co., discussed the testing of supervisory, administrative, and management personnel for the woodworking industry.

Sections to Help Distribute NLMA–FPRS Career Booket

Eight Sections have endorsed the establishment of Industry-Education subcommittees to handle distribution of the NLMA–FPRS career booklet, soon to be published by NLMA, according to Executive Secretary Rovsek. Five of the Sections have already designated committees.

The five Sections are the Florida-Georgia-Alabama, Great Lakes, Mid-South, Mid-West, and Northeast Sections. Three others, the Inland Empire, Rocky Mountain, and Carolinas-Chesapeake will consider creating this type of committee at their next meeting.

Chairman of the F-G-A sub-committee is Rufus Page, Georgia Forestry Commission. Members are John Hamilton, U. of Georgia, D. B. Richards, Alabama Polytechnic Institute, and Jacob Huffman, U. of Florida. Aubrey Wylie, Michigan State U., is chairman of the Great Lakes sub-committee.

Four persons comprise the Mid-South sub-committee. They are: W. C. Hopkins, Louisiana State U., Chrm.; Arne Kemp, Stephen F. Austin State College; David Fisher, Bradley-Southern Div. of Potlatch Forests; and Tom Orth, Kirby Lumber Co.

J. F. Koellisch, editor, Wood and Wood Products magazine, was made chairman of the Mid-West committee at the Section's recent meeting in St. Louis. Members of his committee are D. W. Bensend, Iowa State College, and John Reno, Pacific Lumber Co. Chairman of the Northeast Subcommittee is William T. Nearn, Penn. State U.

First Official Visitor to the Society's New Building

Exec. Sec. Rovsek greets Mr. Naggan, the first visitor to Society's new offices.

First official visitor to the Society's new Executive Offices was Mr. I. Naggan, Tel-Aviv, Israel, a representative for various forest products interests in the Near East. A charter member of FPRS, Mr. Naggan was in the United States to purchase packaging equipment for Israeli industry and to visit the U. S. Forest Products Laboratory.

In discussing the forest products industries in Israel, Mr. Naggan stated that excellent commercial possibilities existed for investment. For each dollar of American capital, he said, Israeli businessmen were willing to invest a like amount. He stressed that the government offered inducements with generous terms for site leasing, taxation and earnings.

He pointed out that while in the U. S. plastic laminates wholesale for around 30 to 40 cents per square foot, in Israel, because of industrial need, they bring $2.00 to $2.50 per square foot.

While in the southern part of the United States on business, Mr. Naggan and an associate from the Saranac Machine Co., Benton Harbor, Mich., attended the Society's Mid-South Section Meeting at Baton Rouge, Louisiana.

Division Growth Reviewed by Berry

FPRS' 14 Divisions are expected to play an increasingly important role in Society activities in the near future, according to Division Coordinator and Vice President R. H. Berry.

Benefits of Division affiliation, Vice President Berry said, are: the opportunity to exchange information with persons in a specific field; the chance to suggest needed research and papers for National and Section meetings; participation in reviews of past achievements; and sharing of problems with others in the same field. Members should be encouraged to affiliate with as many Divisions as they are interested in, he said.

Recent Growth

Slow to develop, the Divisions got their greatest impetus during the 1956–57 National Meetings. Closer cooperation between the Divisions and the National Executive Board was initiated in 1956 at Asheville when the first Division Officers' Advisory meeting was held.

To create more interest in Division activity, a survey of the membership to determine Division interest was requested at Buffalo in 1957. Close to 2,000 responses were tabulated and distributed to officers. At the Madison meeting in 1958 it was agreed that the survey would continue. When members receive their 1959 invoices about Dec. 1, they will have an opportunity to confirm, change, or express interest in additional Division affiliation.

A desire for closer cooperation between Divisions and Sections was expressed at Madison. One step in this direction has been the creation of Industry-Education sub-committees in the Sections at the request of the National Industry-Education Division. These groups will help distribute the "career" booklet published by NLMA, which was originally proposed by the Industry-Education Division.

History

When established in 1950, functions of the Divisions were to aid in the development of strong National Meeting programs and to allow exchange of information between specialists. The Divisions began to broaden their scope when preparation of annual reviews for the JOURNAL was started.

The first Divisions covered Wood Seasoning, Wood Finishing, Education, and Chemical Utilization, and were known as Subject Matter Committees. Instrumental in their formation were R. M. Carter, North Carolina State College, J. F. Hamilton,

R. H. BERRY

R. M. CARTER

Mich. College of Mining & Technology, C. F. Van Epps, Stromberg Carlson Co., and Richard Hertzler, U.S.F.S., then members of the National Executive Board.

Division Projects

An example of long-range Division planning is the Wood-Drying News Digest, originally conceived by R. C. Rietz, USFPL. The News Digest is distributed to more than 2,000 members of dry kiln clubs, and has as its main objective the adoption of better drying methods.

Just coming to fruition is the previously mentioned publication of a career booklet by NLMA. The Lumber Manufacturing Division has recently completed a survey on research needed in sawmilling, and has plans for distribution of this information. Other Division projects include the preparation of bibliographies and lists of patients.

To meet the needs of Division growth, a handbook for Division officers is in the process of preparation by the National Office, Berry announced recently. The handbook, he said, reflects the strengthening of another area of Society activity.

W. R. Warner (second from l.), Chrm. of SPA's Mechanical Efficiency Committee, shown with other committee members.

Southern Pine Assoc. Plans Machinery Show to Coincide with April 1959 Convention

The 1959 Machinery Exposition of the Southern Pine Assoc. will be held April 11, 12, and 13 in New Orleans' Municipal Auditorium, the Assoc. announced recently.

The show will be held in conjunction with the Southern Pine Assoc. convention scheduled April 13, 14, and 15. A brief morning session is slated for the first day to permit maximum attendance at the Machinery Show in its final day.

Plans for the Machinery Exposition were outlined Oct. 9 in New Orleans. W. R. Warner, Bradley-Southern Div., Potlatch Forests, and chairman of the Association's Mechanical Efficiency Committee, was in charge of the meeting, which was attended by representatives of many firms scheduled to exhibit at the 1959 show.

Market Research and Promotion Planned for Western Red Cedar

Sales promotion and need for a comprehensive research program were stressed at the fourth annual meeting of the Western Red Cedar Lumber Assoc., Sept. 11 and 12, at Qualicum Beach, British Columbia.

Keynote speaker of the meeting was Dr. C. D. Orchard, retired Chief Forester of British Columbia. He urged educational programs for architects, builders, and dealers. In other activity, chairman of the industry research committee, Ian McDonald, Norwood Lumber Co. Ltd. of Vancouver, reported findings of the research group.

M. J. Butler, E. C. Miller Cedar Lumber Co., Aberdeen, Wash., chairman of the trade promotion committee, reported that intensive promotion of Western Cedar in selected Canadian and U. S. markets would be an important part of the 1959 program. Promotion activities will include field development, market by market, through clinics for architects and builders on specifying and applying beveled cedar siding.

NAMES IN THE NEWS

Carl A. Rishell, vice president, Timber Engineering Co., Washington, D. C., announced his retirement, December 31, 1958, after a 24-year association with TECO and the National Lumber Manufacturers Assoc. Mr. Rishell first joined NLMA in 1934 and has served as Director of Research for both groups.

Recipient of a $2,000 fellowship established at the University of Wisconsin by the Weyerhaeuser Timber Foundation is **Edward L. Springer,** a graduate student in chemical engineering. In the first phase of his study for a doctoral degree, Springer is carrying on a literature search on processes of lignin removal from wood at the U. S. Forest Products Laboratory, which is operated in Madison in cooperation with the University.

Two research engineers of the U. S. Forest Products Laboratory

have been named to administrative posts, Director J. A. Hall announced recently. **Alan D. Freas** has been appointed assistant to the director, and **Joseph A. Liska** has been named chief of the division of physics and engineering. Freas joined the Laboratory staff in 1939 and Liska in 1941.

Dr. Albert W. Stout has joined Georgia-Pacific Corporation's dept. of research and development at its central laboratory in Hillsboro, Ore., vice president James L. Buckley announced recently. Dr. Stout previously was chief research chemist for the Western Pine Assoc.

NEW PRODUCTS—LITERATURE

New Hollow Cell Core

Gridkore, a hollow cell core designed for sandwich panels, flush door cores, interior partitions, and furniture panels, is now being produced by the Balsa Ecuador Lumber Co.

For panels, the core is formed by notching balsa slats halfway through, and interlocking them in a 4 by 8 inch grid pattern. The grid is first glued to a 4 by 8 foot sheet of 3/8 inch drywall. The grid does not extend to the edge of the drywall sheet, but leaves room for three 2 by 2 members, a joint stud, a plate, and a shoe.

For interior wall partitions, Gridkore is made in 1 5/8 inch thickness and 1/4 inch width. It weighs 1.6 ounces per square foot, and 3.16 pounds per Gridkore panel unit 4 by 8 feet. More information is available from the Balsa Ecuador Lumber Corp., 500 Fifth Ave., New York 36, N. Y.

New Setworks Control Switch

A setworks control switch called an auto-selector is now available from Mater Machine Works, Inc., Corvallis, Ore. The selector was designed to simplify and speed up setting by the sawyer.

The firm reports that where many changes of repeat settings are made, the selector is faster than toggles or push buttons. It can be used to advantage for both hardwood and softwood sawing.

Debarker Chain Specifications

Specifications for a debarker chain for use in the conversion of lumber into wood chips, or other processing, has been issued by the McKay Co., Pittsburgh, Pa. The literature describes the debarker chain and gives an explanation of the operation. Available from the McKay Co., 1005 Liberty Ave., Pittsburg 22, Pa.

New Ply-Veneer Folder

A specification folder on Ply-Veneer, a product made of distended Douglas-fir veneer core and laminated top and bottom with heavy kraft liner board, has been released by the Silvatek Products Div., Weyerhaeuser Timber Co.

Provided in the folder are tables of physical characteristics and specifications on a range of surface variations, thicknesses, and sizes available. Uses in the packaging, luggage, and furniture industries are illustrated. Available from the Silvatek Products Div., Weyerhaeuser Timber Co., Tacoma, Wash.

Vertical Thickness Indicator

A vertical thickness adjustment dial indicator has been released by the Black Bros. Co. Inc., the firm recently reported. It is available as an optional extra on all of the firm's roll type glue spreaders, roller coaters, and rotary presses, and can be added to existing equipment as well as specified on any new machine.

By indicating the opening between the coating rolls in thousands of an inch, the dial is said to enable the operator to quickly adjust the machine to different stock thicknesses from prior settings. More information is available from the Black Bros. Co., Inc., Mendota, Ill.

NEW PUBLICATIONS

Qualification Code for Application to Manufacturers of Structural Glued-Laminated Timber. (First Edition). The code is intended to qualify firms engaged in commercial laminating, and not to inspect, appraise, or approve commercial products. It covers both operating and quality-control personnel, equipment and procedures, and provides for routine testing. After initial examination and approval, the certified fabricator is authorized to issue a standard certificate and to place an approvel label on his product. The presence of the label signifies that the firm producing the product has been found qualified to manufacture it. Established by and available from the Canadian Institute of Timber Construction. 140 Wellington Street, Ottawa.

Soaking Treatment of Basswood at Low Temperatures, as affected by temperature and viscosity of solution, wood moisture, and type of treatment. C. S. Walters. Contains results of a study of the cold-soak method and variables other than anatomical structures that are believed to have the greatest effect on solution absorption and penetration. Bulletin 633, available from the University of Illinois Agricultural Experiment Station, Urbana, Ill.

The following publications are available free of charge from the Ottawa Laboratory, Forest Products Laboratories of Canada, Dept. of Northern Affairs and National Resources, Ottawa, Ontario, Canada.

The Chemical Composition and Pulping Characteristics of Normal and Tension Wood of Aspen, Poplar, and White Elm. L. P. Clermont and F. Bender. Reprint from *Pulp and Paper Magazine of Canada.*

Increasing the Durability of Wood. H. P. Sedziak. Reprint from *Canada Lumberman.*

Electrode Systems for Stray Field Heating. D. G. Miller. Describes some investigations on the design, efficiency, and relative merits of stray field electrode systems for panel-to-frame gluing. Reprint from *Canadian Woodworker.*

The following publications are available free of charge from the U. S. Forest Products Laboratory, North Walnut Street, Madison, Wis.

List of Publications Jan. 1 to June 30, 1958.

Plastic Flow Throughout Volume of Thin Adhesive Bonds. C. B. Norris. Report No. 2092.

Partial List of Publications for Furniture Manufacturers, Woodworking, and Teachers of Wood Shop Practice. Report No. 1775.

A Review of Literature on the Enzymatic Degradation of Cellulose and Wood. Ellis B. Cowling. Report No. 2116.

The FPL Dynamic Compression Testing Equipment for Test Package Cushioning Materials. R. K. Stern. The test described simulates the loading of an item in a cushioned package when the package is impacted. Report No. 2120.

Experiments on the Groundwood and Sulfite Pulping of Subalpine Fir. A. Hyttinen, E. L. Keller, and E. R. Schafer. Papermaking experiments described in the report indicated that subalpine fir groundwood pulps are

suitable for book and newsprint papers. Report No. 2122.

Hardboard from Lodgepole Pine, Engelmann Spruce, and Douglas-fir. S. L. Schwartz. The experimental work carried out was limited to one cooking schedule, several degrees of refining, one pressing schedule, and some heat-treating of the hardboards. Report No. 2123.

Pulping of Northern Whitecedar and Tamarack. A. Hyttinen, E. L. Keller, J. S. Martin, V. C. Setterholm, and R. M. Kingsbury. Describes groundwood, sulfate, and sulfite pulping experiments made on samples of northern whitecedar and tamarack from northern Wisconsin, representative of material available for pulpwood.

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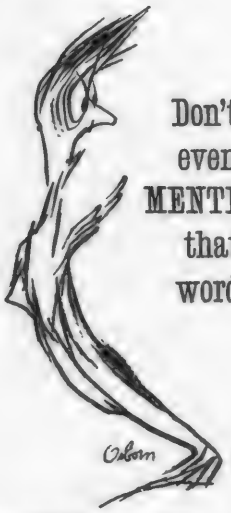

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American Cancer Society

EMPLOYMENT SERVICE

The FPRS Employment Service is operated without charge as a service to members. Companies or institutions with positions to be filled or individuals seeking employment may participate in this program by inserting a free ad in two consecutive issues of the FOREST PRODUCTS JOURNAL. Inquiries concerning employment listings or ads to be placed in the JOURNAL should be addressed to FPRS Employment Service, P. O. Box 2010, University Station, Madison 5, Wis. Correspondence is kept confidential.

Positions Offered

E–321—Wood utilization engineers needed for large furniture manufacturing plant. Experience in furniture and allied fields preferred. Salary commensurate with experience and ability. (Nov.)

E–322—Assistant veneer sales manager needed. A person with an educational background in forest utilization or wood technology preferred but will waive these requirements for a man with equivalent background in veneer sales. Position requires two to four years active veneer sales, making up veneer lines, and pricing veneers. Advancement to position of Sales Manager possible within six to seven years. (Nov.)

E–323—Quality control supervisor needed. Age range desired is 21 to 28 years old. Educational background in wood utilization with an interest in research and quality control preferred rather than sales. Prior business experience will be waived for a recent graduate who has the potential to establish and maintain a systematized quality control program. (Nov.)

E–324—Project engineer needed to perform product design work of substantial importance. Will work under supervision of Product Development Mgr. but will have considerable latitude for independent action and decision. Will occasionally supervise one or more persons in detailing, model-making, and testing. (Dec.)

E–325—Assistant Manager wanted for department dealing with product planning and development in large southern lumber operation. Forestry background desirable with major in wood utilization or industrial engineering. Master's degree preferred. (Dec.)

E–327—Experienced sales manager needed for Pacific Coast sawmill. Must have proven sales ability and should be familiar with sawmills and lumber industry. (Dec.)

Employment Wanted

No. 492—Person with an M. S. in Forest Management desires position. Has experience in logging, photogrammetric work, and forest management research. Married, available Jan. 1, 1959. (Nov.)

No. 493—June 1958 graduate of New York State College of Forestry with B.S. in wood utilization is interested in employment in the wood preservation field. Experienced in operating a small pressure-treating cylinder. (Dec.)

No. 494—Position desired by chemist. Has research experience in plywood adhesives. For the last 4 years has worked as wood preservation specialist on bamboos at India Forest Products Laboratory. Familiar with electron microscopy. Received M.S. degree with honors. Educated in India. Age, 28. Will pay own expenses to come to U. S. (Dec.)

No. 495—Position desired in research or product development with firm producing laminated structures, plywood, or similar products. Holds B.S. in applied sciences and will complete work on M.S. in wood utilization in January 1959. Has research experience in lamination. Prefers South or Southeast location. (Dec.)

No. 496—Production engineer with M.S. in wood technology wants to relocate. Has seven years industrial experience in production supervision, planning and scheduling in furniture manufacturing, plant layout and construction, machine set-up, industrial painting and hydraulics. (Dec.)

No. 497—Product development, sales, or promotion position desired by wood technologist. Experienced in logging, hardboard, production and sales. Holds B.S. and M.S. in forest products and has completed requirements for Ph.D. Currently in production supervision and setting up national distribution outlets. Age, 31. (Dec.)

No. 498—Graduate forester desires position in sales promotion or editorial work. Experienced in forestry, technical writing in wood preservation. Has published in trade magazines, produced company literature, and trade association proceedings. Experienced in selling, warehousing, traffic and purchasing. (Dec.)

No. 499—Position desired in large mill making diversified wood products. Has unusual mechanical ability. Holds B.S. in wood utilization. Experienced in the development of new products, new treating solutions, and plant production. In 1954 was a recipient of an NLMA–TECO summer scholarship. (Dec.)

No. 500—Position in research, technical service, or promotion desired by wood technologist. Has eight years experience in the management of research programs, with emphasis on preservation. Experienced in operation of a commercial treating plant. (Dec.)

No. 501—Position in quality control, production management or practical research desired. Holds B.S. in wood utilization. Experienced in wood finishing. (Dec.)

PRODUCTION SUPERINTENDENT FOR HARDBOARD

West Coast integrated operation needs qualified supervisor assistant to plant superintendent to take charge of production in the hardboard operation. Replies, kept confidential, should state age, experience, and qualifications.

Send replies to:

E-326 Employment Service
FOREST PRODUCTS RESEARCH SOCIETY
P.O. Box 2010, University Station
MADISON 5, WISCONSIN

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CONSULTANT ENGINEERS
Apartado del Este 4575
CARACAS, VENEZUELA

FPRS FOREST PRODUCTS JOURNAL VOL. VIII, NO. 11 NOVEMBER, 1958

Marketable Sawdust Composts

THEIR PREPARATION AND FERTILIZING VALUE[1,2]

S. A. WILDE
Professor of Soils, University of Wisconsin, Madison

Excellent sawdust composts can be produced when anhydrous ammonia is used as the source of nitrogen. The mash is then neutralized with phosphoric acid, innoculated with *coprinus ephemerus*, and aerated regularly.

THE SAWING OF EACH 1000 board feet of lumber produces approximately 1 cubic yard of sawdust, a by-product whose utilization presented in the past a problem nearly as difficult as that of waste liquor. The seemingly logical use of sawdust for improvement of soil fertility was barred by an extremely low content of nutrients and other unfavorable properties of wood.

It is true that the literature includes a number of reports claiming beneficial effect of sawdust and wood chips when such are applied to soils together with a generous dose of commercial fertilizers. Achievements of this kind, however, are closely related to the proverbial soldier's soup prepared from an old axe blade with some "seasoning" of salt, pepper, vegetables, and a large chunk of bacon.

[1] Presented at Session XIII, Chemical Utilization (1), FPRS 12th National Meeting, June 22–27, 1958, Madison, Wis.

[2] A contribution from the Soils Department, Wisconsin Agr. Exp't. Station, Madison, in cooperation with the Wisconsin Conservation Dept. and the Wis. Alumni Research Foundation.

The Author: Sergius Wilde received his PhD from the University of Prague. He came to the U. S. in 1929, and joined the U. W. staff in 1934.

Fig. 1.—Regenerating influence of sawdust compost on Monterey pine raised in soil treated with a combination of biocides (Chlordane, thiosan, and allyl alcohol applied at generally used rates). A. Control, Plainfield sand; B. Similar soil treated with biocides; C. Similar soil treated with biocides and sawdust compost at a rate of 30 cubic yards per acre.

As a matter of fact, the raw sawdust is a much less desirable soil ingredient than the axe blade. If added to the soil in a large quantity, wood of any origin can only upset rather than augment the beneficial influence of fertilizers.

Sawdust includes tannins and phenolic compounds injurious to plants and soil microbes, and it has a high content of cellulose and consequently a high carbon-nitrogen ratio, a property that invariably leads to the impoverishment of soil in nitrates and ammonia consumed by carbohydrate-decomposing organisms.

The only fraction of sawdust that is valuable in the maintenance of soil fertility is lignin. The carboxyl groups of this high-molecular aromatic compound have an ability to part with hydrogen and retain adsorbed ions of ammonia, calcium, magnesium, potassium, and other bases. In this manner, lignin acts as a storehouse of soil nutrients that are preserved from leaching and yet are available to plants through the exchange reactions.

Thus, to convert sawdust into useful soil-improving material, it must be freed of its cellulose and toxic substances. Moreover, to preserve the high capacity of ligneous residue, the end product must possess a nearly neutral reaction, which permits the formation of base-adsorbing carboxyl groups. This was accomplished by a combination of chemical and biological methods—by treatment of sawdust with anhydrous ammonia, neutralization of the mash with phosphoric acid, and by subsequent inoculation with a cellulose-decomposing fungus, *Coprinus ephemerus*.

History of Sawdust Composting

The entire research on the decomposition of sawdust and preparation of sawdust compost occupied a period of 12 years. The use of anhydrous ammonia and phosphoric acid was initiated in 1946 by Voigt and Brener, who aimed to improve the quality of peat composts (7).[3] The drastic alteration of *Sphagnum* peat under the influence of anhydrous ammonia suggested similar trials with sawdust, which were carried out by Davey (2). When

[3] Numbers in parentheses refer to the Literature Cited.

chemically treated sawdust was enriched in hardwood-hemlock leaf mold, commonly used in the preparation of Wisconsin nursery composts, the mixture produced an abundant crop of mushrooms. These were identified by the late Dr. Audrey Richards of the U. S. Forest Products Laboratory as *Coprinus ephemerus,* a species of a very high cellulolytic capacity.

Following the detailed study of the desirable rate of ammonia application, neutralization procedure, and enrichment of material in other nutrients, particularly potassium, Davey succeeded in preparation of a compost that proved to be beneficial to field and forest crops. At a later date, Davey (3), working with Drs. L. E. Wise and B. L. Browning in the Appleton Institute of Paper Chemistry, established the rate of cellulose decomposition and subsequent increase in exchange capacity of the fermented sawdust.

Beginning with 1954, a method was devised for the preparation of sawdust composts on a scale satisfying the requirements of large forest nurseries. The sawdust was placed in 4-foot-deep piles of several hundred cubic yards each, and was treated by probing with anhydrous ammonia at the rate of 10 to 14 pounds per cubic yard. After 10 days, the treated material was spread as a 6-inch top dressing, and its pH of nearly 11 was neutralized by a 4 per cent solution of phosphoric acid, applied by means of a multi-sprayer (1). Simultaneously, the sawdust was enriched in potassium sulfate. A few days later, the sawdust was inoculated with previously fermented compost, applied by a manure spreader at a rate of about 1 per cent by volume. The mixture then was rototilled into the soil to an approximate depth of 8 inches, and was allowed to ferment.

Depending on circumstances, the composting was accomplished on a cut-over area or directly on nursery blocks. During the growing season, the period necessary for conversion of sawdust into black, mull-like ligneous material did not exceed two months. Because of the nursery working schedule, however, composts usually were prepared in the fall and used the following spring.

Modifications of Initial Process

The beneficial influence of sawdust compost applications in two of the Wisconsin State Forest Nurseries indicated a happy solution of the sawdust compost problem, and this remains true until today, as far as the nursery practice is concerned. Several modifications, however, were necessitated when an attempt was made to prepare a marketable product for improvement of soil fertility in truck gardens, orchards, landscape plantings, greenhouses, and potted plants.

First of all, it was highly desirable to eliminate the cumbersome and laborer-taxing treatment of sawdust by probing. This was successfully accomplished by using a motor-operated pipe-auger unit commonly used for grain storage (Cover). The injection of ammonia into the sawdust-carrying pipe has mechanized the process, effected more thorough and uniform treatment of sawdust, and permitted an economy of the chemical. The neutralization of the ammonia-treated sawdust with phosphoric acid and enrichment of the material in potassium sulfate were facilitated by installation of pressure spraying equipment with controlled discharge. The mechanization of the sawdust treatment was developed largely by M. D. Woerpel of the Wisconsin Alumni Research Foundation and several graduate students of the University of Wisconsin, particularly R. A. Schmaedick, M. B. Palmer, and H. H. Krause.

Next, the initiation of a large-scale composting of sawdust required preparation of a sufficient supply of inoculum, or actively fermenting sawdust with abundant mycelia of the fungus *Coprinus ephemerus.* Because of the importance of this phase of the composting process, a method that proved to be most efficient in the preparation of inoculum is described in detail (9).

In fermenting sawdust for local consumption, such as for use in forest nurseries or truck gardens, the time element is of minor importance because the fertilizer is applied only once a year. Therefore, the logical way to prepare compost is to rototill the inoculated sawdust into the soil of a sandy texture or an aggregated structure. Such media provide adequate aeration, and usually a sufficient supply of moisture is delivered by precipitation.

The commercial production of sawdust compost requires a shortening of the period of fermentation to the possible minimum. Moreover, the rototilling of the sawdust into the soil considerably increases the volume and weight of the final product and raises the transportation cost. Therefore composting is best accomplished in piles periodically watered and aerated by the use of portable gasoline or electrically operated pumps and a framework of perforated pipes.

Under favorable conditions of temperature, moisture, and aeration, the sawdust of most tree species of the temperate zone can be decomposed in as brief a period as four weeks. Although the literature includes statements to the effect that sawdust can be decomposed in the period of several days or even 24 hours, research at Wisconsin thus far has failed to provide any support to the validity of such claims.

Field Trial Results

An interesting detail connected with this method of sawdust composting is that the fungi are usually assisted in

How to Prepare the Inoculum

A battery of 50-gallon barrels is placed in a shed or other structure where ammonia fumes will not be objectionable. The barrels are filled with fresh sawdust, preferably that of hard maple, and treated with anhydrous ammonia at the rate of 12 pounds per cubic yard, or 3 pounds per 50-gallon barrel. For this purpose, anhydrous ammonia is procured in a small 50 or 100 pound cylinder and applied with the use of a metering device, heavy rubber hose, and a hollow aluminum probe. The probe, 4 feet long and 11/16 inch in outside diameter, is closed on the end and perforated spirally by 1/64 inch holes with ½ inch spacing. The radius of dispersion of the ammonia does not exceed 1 foot, and hence 3 probes properly spaced and delivering 1 pound of ammonia each are necessary for treatment of a single barrel. No other form of nitrogen except anhydrous ammonia will serve the purpose. The operator should take precaution against inhaling ammonia fumes.

The treated sawdust is left undisturbed for one week, and is then removed from the barrel, spread on the floor, and neutralized with a solution of phosphoric acid prepared by pouring 130 ml. of commercial 85 per cent phosphoric acid into 4 gallons of water. The solution is applied with a sprinkling can. Then 1 pound of 50 per cent potassium sulfate is dissolved in about 2 gallons of water, and this solution is also sprinkled on the sawdust.

The material is thoroughly reworked with a shovel and left on the ground for a few days, after which about 1 gallon of inoculum, previously prepared or secured from our laboratory, is spread over 50 gallons of treated material. If conditions permit, it is advisable to spread also 2 gallons of leaf mold or a few gallons of top soil. The addition of these materials is desirable, but not absolutely necessary. The sawdust is thoroughly mixed, and placed in the barrels for composting. The material is kept moist by periodic watering and is frequently aerated. The aeration can be accomplished by the aluminum probe attached to an air compressor. Otherwise, the compost can be occasionally remixed. If the composting medium is prepared satisfactorily within a few weeks, the appearance of fruiting bodies of *Coprinus ephemerus* will indicate the success of the inoculation (Fig. 2).

Simultaneously, all the sawdust becomes permeated with white fungal hyphae and attains a temperature of above 100° F. At this stage, the medium is suitable for inoculation of other chemically treated sawdust. Ordinarily, it is sufficient to use 1 per cent of inoculum for the preparation of a large quantity of sawdust compost.

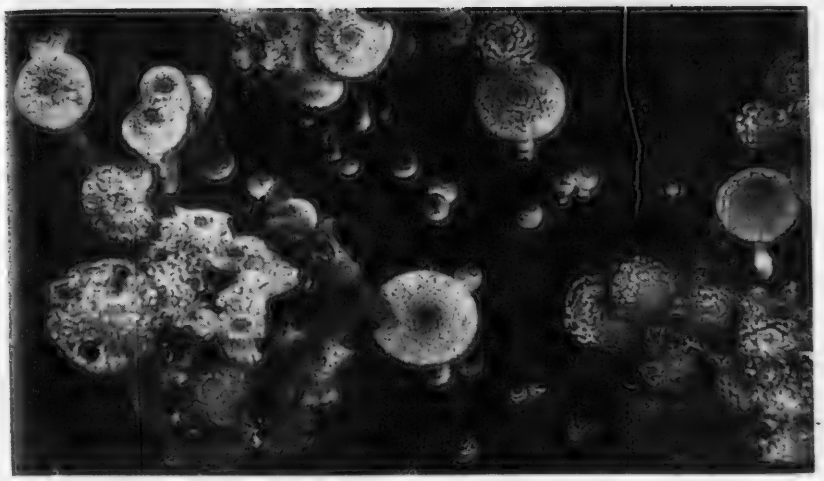

Fig. 2.—Abundant crop of fruiting bodies of Coprinus ephemerus reveals the success of inoculation of chemically treated sawdust.

the decomposition by the larvae of *Sciaridae*, or "fungus gnats." Under field conditions, and even in greenhouses, these organisms invade as volunteers the partly fermented material in immense numbers and in a rather mysterious way. This invasion serves as one of the most striking illustrations of the life-giving influence of the source of food, as well as of the symbiotic association of fungi and insects.

Finally, a marketable fertilizer product must utilize to the maximum the capacity of fermented sawdust to retain positively charged nutrient ions. Depending on the prospective use, the sawdust may be still further enriched in major and trace elements. This task is easily accomplished by spraying the fermented material with a solution of the desired composition. The relative concentration of nutrient ingredients in the finished product is dictated by the requirements of crops, and is a concern of specialists in the fertilizer industry.

Fig. 3 illustrates the effect of compost on the growth of corn raised in a coarse sandy soil with unimpeded drainage. The increased growth in this case is largely due to the retention of soluble fertilizer salts by the ligneous residue, which possesses high exchange capacity. Fig. 4 presents one of the most spectacular results of the trials, obtained with radishes. In these cultures, the beneficial effect of the compost became sharply pronounced 48 hours after germination, a reaction uncommon with mineral fertilizers.

Mineral fertilizers cannot produce the over-all beneficial effect on plants equal to that obtained with combined organo-mineral fertilizers, be they in the form of composts, organic briquettes, or liquid humates (8, 11). The superior efficiency of organic fertilizers is due to the stability and the gradual release of nitrogen, prevention of phosphate fixation, an increased availability of iron and other nutrients, and also causes which we may not fully understand. But in the work reported here, undeniable evidence has been obtained that organic matter may convert some of the extremely toxic hydrocarbons into completely harmless compounds or even into growth-promoting substances of high efficiency (10).

In this connection, it should be pointed out that the maximum favorable influence of sawdust compost is exerted in soils treated with biocidic compounds designed to exterminate parasitic fungi, harmful insects, and noxious weeds. More than once, the ill consequences of the indiscriminate use of toxic eradicants in forest nurseries has been seen. Repeated application of these substances without special precautions disrupts the activity of useful soil microorganisms, arrests the release of available nutrients, and cripples the growing stock (5, 6).

Therefore, it is highly satisfying to report the results of investigations conducted in our laboratory by Mitsuma Matsui. His trials proved conclusively that sawdust composts are among the few materials that counteract the ill effects of eradicants, restore soil fertility, and permit production of vigorous planting stock on biocide-treated soils. These results present the most important accomplishment obtained in the course of our many years of research in forest soils and tree nutrition.

Fig. 1. exemplifies the effect of sawdust compost on the growth of tree seedlings raised in biocide-treated soils.

As has been shown previously by Mader (4), the use of readily soluble fertilizer salts usually greatly amplifies the harmful influence of biocidic compounds; application of an equivalent amount of the same fertilizers in the form of compost has a far-reaching beneficial effect.

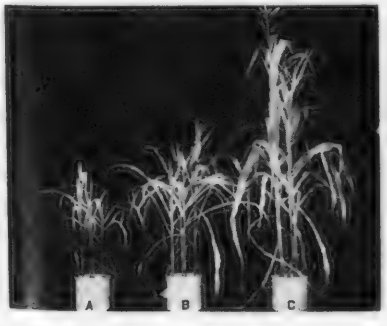

Fig. 3.—Effect of sawdust compost on the growth of corn in greenhouse cultures with unimpeded drainage. A. Control, outwash Plainfield sand; B. Similar soil treated with 500 pounds of 10–10–10–fertilizer per acre; C. Similar soil treated with 30 cubic yards of sawdust compost per acre.

Fig. 4.—Effect of sawdust compost on the early development of radishes. A. Control, Plainfield outwash sand; B. Similar soil treated with 30 cubic yards of sawdust compost per acre. Photograph taken four days after germination.

Literature Cited

1. Brener, W. H. 1939. Multiple use sprayer for the application of liquid fertilizers, insecticides, and soil disinfectants in forest nurseries. Jour. For. 37: 630.
2. Davey, C. B. 1953. Sawdust composts; their preparation and effect on plant growth. Soil Sci. Soc. Am. Proc. 17: 59–60.
3. Davey, C. B. 1955. Transformations of sawdust in the course of its decomposition under the influence of *Coprinus ephemerus*. Soil Sci. Soc. Proc. 19: 376–377.
4. Mader, D. L. 1956. Effect of humus of different origin in moderating the toxicity of biocides. Ph.D. thesis, University of Wisconsin Library, Madison, Wisconsin.
5. Persidsky, D. J., and S. A. Wilde. 1955. Effect of eradicants on the microbiological properties of nursery soils. Wis. Acad. Sci., Arts, Lett. 44: 65–73.
6. Voigt, G. K. 1955. The effect of applied fungicides, herbicides and insecticides on the content of nutrient elements in tissue of coniferous seedlings. Soil Sci. Soc. Am. Proc. 19: 237–239.
7. Voigt, G. K., W. H. Brener, and S. A. Wilde. 1950. Liquid ammonia treatments of composted fertilizers. Soil Sci. Soc. Am. Proc. 14: 281–284.

8. Wilde, S. A. 1937. The use of liquid humate fertilizers in forest nurseries. Jour. For. 35: 388–392.
9. Wilde, S. A., C. B. Davey, and H. Loewenstein. 1956. Preparation of inoculum of *Coprinus ephemerus* for sawdust composts. Techn. Notes No. 55, Wis. Cons. Dept. & Wis. Coll. Agr., Madison, Wis.
10. Wilde, S. A., G. K. Voigt, and D. J. Persidsky. 1956. Transmitted effect of allyl alcohol on growth of Monterey pine seedlings. For. Sci. 2: 58–59.
11. Wilde, S. A., and R. Wittenkamp. 1942. Duff briquette fertilizers: their preparation, use, and effect upon the growth of trees and other plants. Jour. Am. Soc. Agr. 34: 736–746.

Discussion

H. N. Calderwood (Consultant): What is the cost of preparing the sawdust for compost?

Dr. Wilde: The cost of compost preparation varies, depending upon the output and mechanization of the process, but usually it should not greatly exceed $1 per cubic yard. The cost of reinforced, commercially produced sawdust compost, according to the recent estimate of the Wisconsin Alumni Research Foundation, would be about $20 per ton. The incorporated nutrient elements, nitrogen, phosphorus, and potassium, present by far the greater part of the cost.

R. C. Sproull (Philip Morris, Inc.): Do you experience more rapid flowering when you use sawdust composts?

Dr. Wilde: Definitely so, provided that the soil, after the application of compost, does not have an excess of available nitrogen, a condition that delays flowering.

C. A. Watson (Puget Sound Pulp & Timber): Has any attempt been made to analyze and control trace element concentration in your control and compost tests?

Dr. Wilde: The sawdust invariably contains some small amount of trace elements, but we are considering an addition of minute quantities of boron, manganese, copper, zinc, and molybdenum for use on soils deficient in these rare nutrients. We are now studying the availability of trace elements and detection of these nutrients by analytical methods, but there is still a pronounced dearth of information on this subject.

Yale Weinstein (N. M. Timber Co.): Did you use more than one species?

Dr. Wilde: Yes, we used maple, paper birch, aspen, jack pine, and a few other species.

Anon.: Was hemlock sawdust used?

Dr. Wilde: Only as an incidental admixture to sawdust of other species.

M. Yoshimura (Yale University): How do you think sawdust or sawdust compost would affect the fertility of the soil if it were given to the same area for a period of say 20 years?

Dr. Wilde: I believe that the application of sawdust, like that of any other form of fertilizer, should be made in conjunction with soil analyses. When the soil attains a level of fertility characterized by 0.2 per cent of total nitrogen, 70 pounds of available phosphorus per acre, and 200 pounds of available potassium per acre, the application of compost for a great majority of crops is likely to become an uneconomical practice.

Dowel Joint Strength

EFFECT OF DOWEL TYPE, HOLE SIZE, AND ADHESIVE

W. T. Nearn and J. T. Clarke
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This follow-up study shows that: compressed dowels produce stronger joints than do spiral dowels, which are still better than regular dowels; the dowel hole should be slightly larger than the pin; and polyvinyl resins are excellent dowel glues, with a hot animal glue also very good.

Photo courtesy Heywood–Wakefield Co.

In a previous study[2], as to the effect of dowel type and hole size on joint strength, the conclusion was drawn that a joint in which the dowel was inserted into a hole 1 or 2/64ths inch larger than the dowel pin was superior to one in which the dowel was inserted into a hole essentially equal to the dowel diameter or oversized to the extent of more than 2/64ths inch. It was noted also that the spiral and regular dowels produced stronger joints than the compressed dowel. Observations made during the study showed that the compressed dowel was not fully expanded under the existing test conditions.

The presentation of this information

[1] A contributed paper (received May, 1958) authorized for publicaton in the Journal Series of the Pennsylvania Agr. Expt. Station as paper No. 2188.

[2] Nearn, W. T., N. A. Norton, and W. K. Murphey. 1953. The strength of dowel joints as affected by hole size and type of dowel. Jour. FPRS, III: 4.

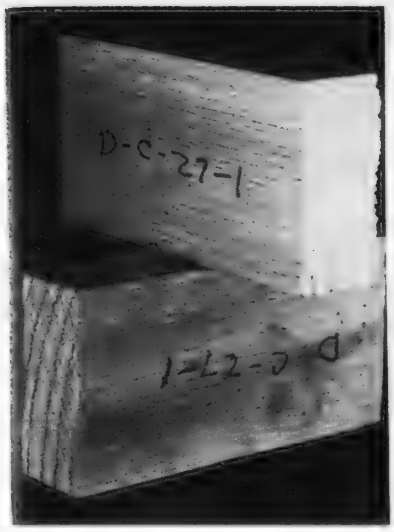


Fig. 1.—Dowel test specimen.

led to a number of questions for which adequate answers were lacking. For example: What would be the results if several rather than a single glue were used? What effect would simulated service conditions have on the results? Is it possible that the type of test specimen used biased the results by failing to provide a glue reservoir to facilitate expansion of the compressed dowel and by allowing the size of the dowel hole to exert undue influence on the secondary glue line that was present in the test specimen?

In an attempt to answer the foregoing questions, a new series of tests were undertaken.

Procedure

The specimen used in this study is shown in Fig. 1. This particular joint was described by Selbo and Olsen[3] and later referred to by Olsen and Blomquist[4] as being "relatively simple to make and to test with some precision." A preliminary study of the usefulness of several possible dowel test joints confirmed the preceding statement. All tests were performed with a Tinius Olsen 100,000-pound-capacity universal testing machine to load the dowel joint specimen so as to apply a tensile force on the glue joint as shown in Fig. 2.

Table 1.—GLUES USED IN DOWEL STUDY

Designation	Type of Glue	Preparation
Glue A	Aliphatic resin-based, water-dispersed	Used as received
B	Polyvinyl resin	Used as received
C	Liquid hide glue	Used as received
D	Hide glue, grade No. 8	1.75 lbs. water to 1 lb. glue, applied at approximately 140° F.

The experimental design followed may best be described by reference to Fig. 3. It includes three variables: glues, dowel type, and hole size, and is laid out so that every possible combination of the three is replicated five times.

The four glues used in this experiment and the designation employed with each are given in Table 1. The dowels were commercially manufactured of birch, nominal 3/8ths inch in diameter, and were of three types, regular, compressed, and spiral. The material used in fabricating the test blocks was straight-grained, defect-free, kiln-dried red oak. In manufacturing the specimens, glue was spread both on the dowel and in the dowel hole. A piece of waxed paper with a hole through it was placed between the joint members, and the two members were aligned at right angles and clamped with C clamps. They were then removed from the clamps and allowed to remain undisturbed for a period of at least seven days.

Prior to test, the specimens were placed in a conditioning chamber for 15 days. During this time, conditions within the chamber were adjusted so that the moisture content of the specimens was raised from approximately 6 per cent to approximately 12 per cent, followed by a return to 6 per cent. All specimens were subjected to three such cycles. The entire experiment as described above was repeated a second time.

Fig. 2.—Specimen in position for test.

Results and Analysis

The average joint strength obtained with each dowel, glue, and hole-size combination is listed in Table 2. The meaning of these values, which are an average of five replications, may best be interpreted by means of an analysis of variance (Table 3).

Table 3 shows that there is no significant difference between experiments when the differences are compared to the variability that exists within experiments due to dowels and glues. There are significant differences within experiments due to the main effect of dowels and glues, and there is an indication that the effect of hole size is significant. A physical interpretation of the main effects may best be given by reference to Fig. 4, which pictures

DOWEL	REGULAR (R)				COMPRESSED (C)				SPIRAL (S)			
HOLE SIZE	24	25	26	27	24	25	26	27	24	25	26	27
GLUE A	5	5	5	5	5	5	5	5	5	5	5	5
B	–	–	–	–	–	–	–	–	–	–	–	–
C	–	–	–	–	–	–	–	–	–	–	–	–
D	–	–	–	–	–	–	–	–	–	–	–	–

Fig. 3.—Experimental design.

Table 2.—AVERAGE JOINT STRENGTH FOR ALL DOWEL, GLUE, AND HOLE SIZE COMBINATIONS

		Experiment No. 1				Experiment No. 2			
		Hole size, 64ths of an inch				Hole size, 64ths of an inch			
Glue	Dowel	24	25	26	27	24	25	26	27
A	R	395	313	324	443	124	314	278	330
	C	586	954	1055	928	526	981	727	708
	S	396	620	464	402	383	296	372	414
B	R	397	697	856	814	368	619	574	492
	C	1132	1352	1241	1059	767	781	930	793
	S	723	909	909	813	465	607	529	530
C	R	334	229	467	438	246	370	530	694
	C	718	741	813	656	821	920	985	1085
	S	630	774	514	550	717	836	682	712
D	R	532	323	394	285	273	541	886	832
	C	1048	833	618	818	912	818	1053	959
	S	1025	884	904	883	655	707	1038	997

[3] Selbo, M. L., and W. Z. Olsen. 1953. Durability of woodworking glues in different types of assembly joints. Jour. FPRS, III, No. 5.

[4] Olsen, W. Z., and R. F. Blomquist. 1955. Polyvinyl-resin emulsion woodworking glues. Jour. FPRS, V, No. 4.

The Authors: William Nearn received his BS degree from New York State College of Forestry and MF and DF degrees from Yale School of Forestry.

John Clarke holds BS and MF degrees from the Penn State School of Forestry.

Photos courtesy Wells Furniture Co.

After the back is assembled . . . the seat is formed . . . all with dowels.

the over-all differences that may be attributed to the effects of hole size, dowel type, and glue.

It may be noted in Fig. 4 that in both experiments there is a slight trend toward an increase in joint strength as hole size increases. This is more prominent in experiment 2 than it is in experiment 1. The indication of significance shown in Table 3 is due almost entirely to the differences that exist between the 24/64 hole and the larger hole sizes in experiment 2. A general conclusion may be made to the effect that, although there is a slight increase in joint strength as a result of using an oversized dowel hole, this effect is minor when compared to that brought about by certain combinations of glues and holes.

That there is a pronounced effect in joint strength due to the type of glue used is evident from both Table 3 and Fig. 4. Further comments concerning glues must be qualified because glues B and C behaved somewhat differently within the two experiments. An initial conclusion may be drawn that glues B, C, and D produce better dowel joints than glue A.

On the basis of experiment 1, it may be concluded that glues B and D will produce a dowel joint superior to the one made with glue C. Experiment 2, however, shows glue D and C to be better than glue B. If one considers the highest values that appear in Table 2, and the magnitude of the difference in values between experiment 1 and 2, a justifiable conclusion would seem to be that, in general, glues B and D will form a stronger dowel joint than glues A and C, regardless of the type of dowel and size dowel hole used.

The main effect of dowels is relatively easy to interpret. As is shown in Fig. 4, the compressed dowel produced superior joints, regardless of the type of glue or the size hole into which it was inserted. The spiral dowel produced the next highest joint strength, with the regular dowel giving the poorest performance. The differences noted above were consistent within the two experiments.

The significant interactions of Table 3 are of as much interest to the user of dowels as they are to the statistician. The physical meaning of these interactions may best be understood by reference to Figs. 5A, B, and C.

The glue x dowel interaction is pictured in Fig. 5A. When used with glues A, B, and C, the compressed dowel produced joints of greater strength than did either the spiral or the regular dowel. When used with glue D, however, the compressed dowel had a joint strength that was essentially equal to that of the spiral dowel. This typifies what is meant by the term interaction. From a practical point of view, it leads to the conclusion that, of the glues tested, glue D is the best for use with a spiral dowel.

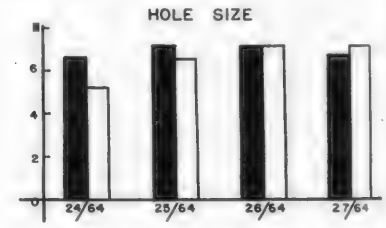
The glue x hole interaction, which is shown in Fig. 5B, is not quite so apparent as the glue x dowel interaction. It can be seen, however, that the effect of hole size with glues A and B is somewhat different than it is with glues C and D. With the former, the 25 and 26/64th inch holes produced stronger joints that did the 24 and 27/64th inch holes. In the latter instance, there is either a continuous increase or continuous decrease as hole size increases. This leads to the conclusion that, with glues A and B, it is more advantageous to use a slightly larger dowel hole than it is with glues C and D.

The dowel x hole interaction is shown in Fig. 5C. It indicates that the effect of hole size is more pronounced when a regular dowel is used than it is with either a spiral or compressed dowel. This is quite logical, since the tendency of a tight fit to strip the glue from a regular dowel would not exist with either a spiral or compressed dowel because of the fluted configuration of one and the spiral and vertical channels of the other.

Table 3.—ANALYSIS OF VARIANCE FOR ALL DOWEL, GLUE, AND HOLE-SIZE COMBINATIONS

Variation due to		Degrees of freedom	Sum of squares	Mean squares	F
Experiments		1	160,626	160,626	N.S.
Dowels	(within experiments)	4	14,703,460	3,675,865	164***
Glues	(within experiments)	6	8,627,038	1,437,839	11.9***
Holes	(within experiments)	6	1,642,485	273,747	2.27+
D x G	(within experiments)	12	2,712,541	226,045	10.13***
D x H	(within experiments)	12	788,353	65,696	2.94***
H x G	(within experiments)	18	2,170,072	120,559	5.40***
D x G x H	(within experiments)	36	2,003,250	55,562	2.49***
Subtotal		95	32,807,825		
Residual		384	8,567,497	22,311	
Total		479	41,375,322		

[1] ***—Significant at 0.1 per cent level.
+ —Significant at 10 per cent level.



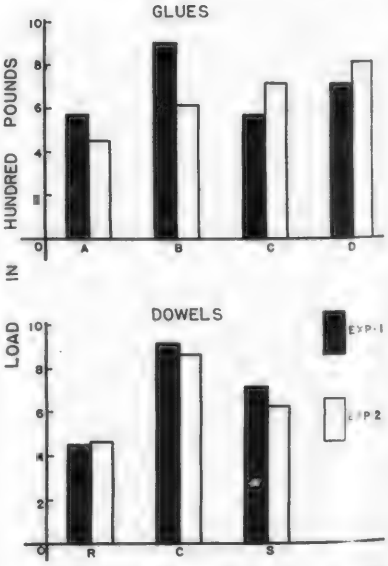


Fig. 4.—Averdage effect of hole size, glue and dowel type on joint strength

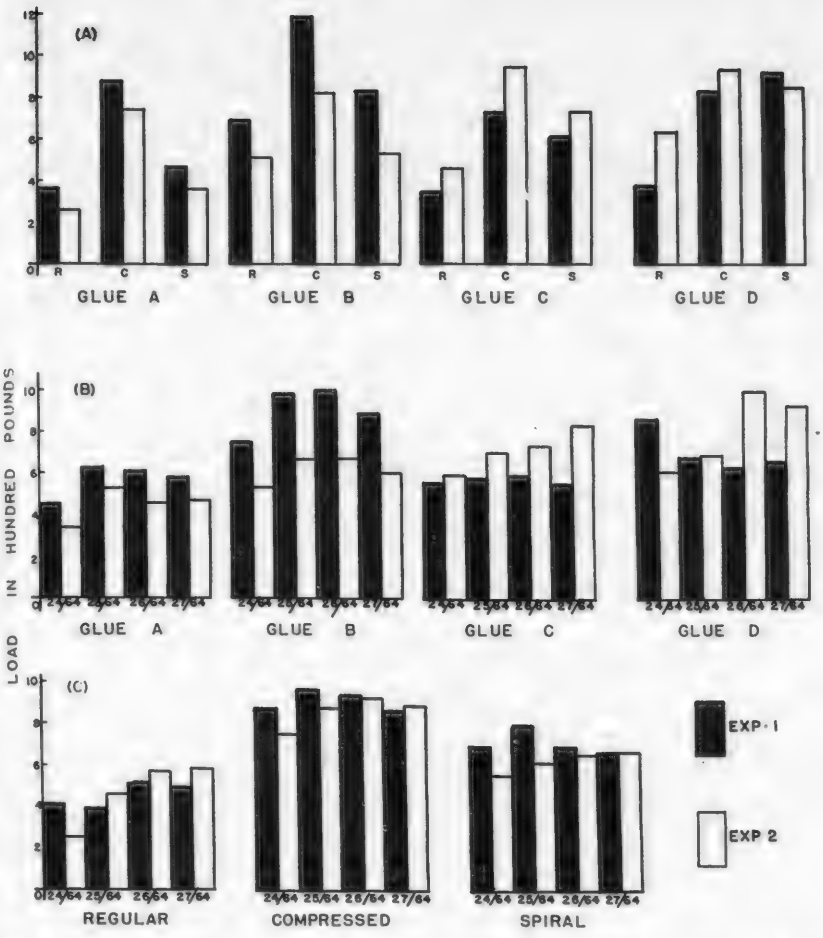


Fig. 5.—Effect of various combinations of dowel type, hole size, and glue on the strength of dowel joints. R, C, and S indicate regular, compressed, and spiral dowels, respectively.

A point worthy of discussion is the differences that exist between the results of the current experiment and the one previously reported.[2]

The original study indicated that spiral and regular dowels produced joints superior to the compressed dowels, while the current study indicates that the compressed dowels produced joints superior to the spiral and regular dowels. These two opposite conclusions may best be reconciled by noting that, in the time which elapsed between the two studies, the manufacturer redesigned his compressed dowels. The dowel pin now has 12 ridges and grooves instead of eight. In addition, the grooves are not as deep as they were originally.

This change in design apparently assures full expansion from the moisture available in the adhesive, as evidenced by the fact that all compressed dowels used in this study were fully expanded while the majority of those used in the original study underwent far less than what may be termed full expansion. There is no doubt that the current product represents a vast improvement over the old.

In the original study, the effect of dowel-hole size was much more pronounced than in the study being reported. A possible explanation may be found by considering the effect of a change in specimen design on the results. The original specimen was a modified version of the standard test specimen used in determining the strength of wood in tension perpendicular to the grain. As such, it contained two glue lines, and the hole into which the dowel was inserted was drilled completely through the specimen. These two factors may have combined to produce low test values when a 24/64 inch dowel was inserted into a 24/64 inch hole. The hole would prevent the formation of a good glue joint between the two halves of the test specimen, and at the same time cause the glue to be stripped from the dowel and forced out of the open dowel hole. With the type of specimen used in the current study, neither of these factors would be operative.

While it is not the purpose of this paper to discuss in detail why the glues studied behaved as they did, it is necessary to comment briefly as to the comparison between the results of these tests and those reported by Olsen and Blomquist[4]. The results are comparable in that both studies indicate that the polyvinyl resins are excellent glues for use in dowel joints. The difference between animal glue and polyvinyl resin, however, was not so great in this study as it was in the work at the Forest Products Laboratory. It should be remembered, however, that the objectives of the two studies were not the same, and that only a single polyvinyl resin was used in this series of tests while a number of polyvinyls were tested by Olsen and Blomquist.

Conclusions

Based on the results obtained in this series of tests, the following conclusions may be drawn:

1. Glue A, a polyvinyl resin, and glue D, a hot animal glue, produced stronger dowel joints than did either of the other glues studied.

2. In general, compressed dowels give stronger joints than do spiral dowels, and spiral dowels produce stronger joints than do regular dowels. When used with a hot animal glue, spiral dowels produced joints essentially equal to those of compressed dowel joints.

3. The use of a dowel hole slightly larger in diameter than the dowel pin will tend to increase joint strength. This effect was more apparent with the two resin glues than it was with the two animal glues. The general effect of hole size was more noticeable with the regular dowels than with the spiral and compressed dowels.

The Strain Behavior of Wood

IN TENSION PARALLEL TO THE GRAIN[1, 2]

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Short-term creep tests indicate that the creep-stress level relation may be described by a linear regression up to the threshold of set and an exponential regression thereafter. Permanent set begins at about the same initial strain, but the stress level at which set first occurs varies considerably between species.

FOR MANY YEARS, conventional elastic theory has been used to predict the behavior of wood under stress and, through its use, a large number of problems of design and processing have been solved successfully. From the standpoint of fundamental rheological behavior, however, the traditional concepts of proportional limit and linearity of the stress-strain relationship do not provide an accurate description of the true strain behavior of wood. This insufficiency has been exemplified by numerous investigations which have shown that wood, under all types of loading, exhibits creep well below the standard proportional limit stresses (1–3, 7–12, 14–16).[3]

This report presents some results of short-term creep tests designed to provide information on the elastic and viscous properties of wood in tension parallel to the grain. The objective of the investigation was to contribute to a better understanding of the time-dependent strain behavior of wood while under stress.

Results of short-term creep tests on basswood, red oak, Douglas-fir, cedro branco *(Cedrela huberi)*, determa *(Ocotea rubra)*, angelique *(Dicorynia paraensis)*, timbauba, *(Enterolobium Schomburgkii)*, and kaneelhart *(Licaria cayennensis)* are presented in this paper. These eight species provided a range of wood specific gravity from 0.40 to 1.04.

Test Procedure

A detailed description of the test procedure was given in an earlier paper (6). Consequently, only the primary features of the test procedure are set forth here.

Measurements of creep were taken over a 30-minute sustained-load period for stress levels ranging from 6 to 86 per cent of ultimate tensile strength. Each species was represented by specimens from three boards and, where possible, these boards were taken from different logs.

The type B tension specimen described in ASTM D805–52 was used. All specimens were tested at a nominal moisture content of 12 per cent and at a temperature within the range of 75 to 85° F. Strain was measured to the nearest microinch (± 1½ microinches) with an SR-4, A-5 paper-mounted electrical resistance strain gage bonded to each specimen. A Baldwin strain analyzer was employed as a strain sensing device.

After a 14-minute warm-up period for both the compensating and active strain gages, each test specimen was loaded to the desired stress level in one minute. Load was applied by means of Templin self-aligning and self-tightening grips in a Baldwin-Southwark hydraulic testing machine. Upon completion of all sustained-load tests for a given species, each specimen was tested to failure at a platen speed of 0.035 inch per minute.

Experimental creep values were corrected for zero drift. Drift correction factors were determined by measuring the change in the zero (or unloaded) strain reading of each pair of specimens (the active test specimen and the specimen providing the compensating gage) over a 30-minute period after allowing a 15-minute warm-up period.

Approximate thresholds of permanent set were determined by testing each of a number of specimens at successively higher stress levels until significant set occurred, as shown by an increase in the unloaded strain measurement. Specimens tested in this manner were not reloaded until recovery was virtually complete. Unloaded

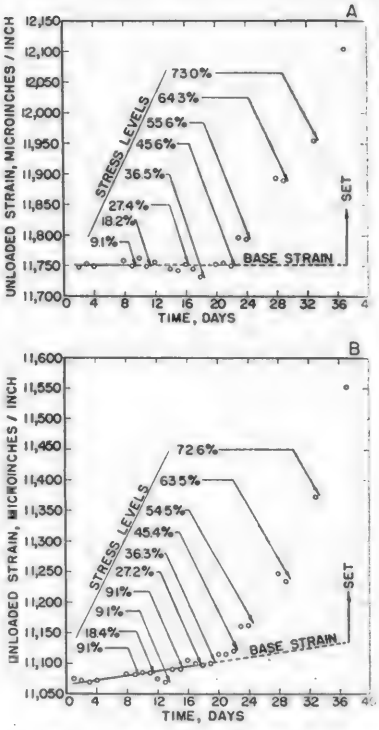

Fig. 1.—Unloaded strain-stress level-time relationships for two specimens tested in stepwise fashion at successively higher stress levels. Stress levels expressed as a percentage of the average ultimate strength of control specimens. A. Oak. B. Cedro branco.

What This Research Means

Conventional static testing methods fail to provide information as to the behavior of wood under long time loads. Necessary design data such as safe allowable loads and magnitudes of creep, are supplied currently through dead-load tests that extend over several years.

Another approach to the problem is to determine the fundamental nature of the time-dependent strain behavior of wood through short-term tests. Knowledge of the essential character of such strain behavior would be helpful in establishing more precise design criteria. This paper contributes to that effort.

—Editor

[1] A 1958 Wood Award Entry.

[2] This research is part of a comprehensive study being conducted at the Yale School of Forestry in cooperation with the Office of Naval Research, Department of the Navy, under Contract Nonr 609(13), Project NR 330–001, Properties of Tropical Woods.

[3] Numbers in parentheses refer to Literature Cited.

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Table 1.—SPECIFIC GRAVITY, ULTIMATE TENSILE STRENGTH, AND REGRESSION DATA FOR EIGHT DOMESTIC AND TROPICAL WOODS

Species	Specific gravity (O.D. vol.)	Average ultimate tensile strength psi	Regressions[1]	Stress level range of fitted experimental data per cent	Number of tests
Basswood	0.40	11,920	Linear: $\Delta\epsilon = -13.1802 + 2.5840\sigma_L$	6–35	14
			Exponential: $\Delta\epsilon = e^{(2.7923 + 0.04540\sigma_L)}$	30–86	9
Cedro branco	.46	15,990	Linear: $\Delta\epsilon = -5.5989 + 1.3656\sigma_L$	9–42	12
			Exponential: $\Delta\epsilon = e^{(2.5308 + 0.03463\sigma_L)}$	40–86	17
Determa	.52	10,320	Linear: $\Delta\epsilon = -13.9194 + 1.6577\sigma_L$	10–49	18
			Exponential: $\Delta\epsilon = e^{(2.4368 + 0.03677\sigma_L)}$	37–80	19
Douglas-fir	.56	19,880	Linear: $\Delta\epsilon = -5.2945 + 0.7474\sigma_L$	14–52	20
			Exponential: $\Delta\epsilon = e^{(2.0615 + 0.02926\sigma_L)}$	46–75	14
Red oak	.64	19,850	Linear: $\Delta\epsilon = -12.4056 + 3.2897\sigma_L$	10–39	12
			Exponential: $\Delta\epsilon = e^{(3.3206 + 0.03903\sigma_L)}$	33–84	16
Angelique	.78	26,050	Linear: $\Delta\epsilon = -10.9398 + 1.0680\sigma_L$	9–38	7
			Exponential: $\Delta\epsilon = e^{(2.1313 + 0.03485\sigma_L)}$	42–83	13
Timbauba	.94	34,920	Linear: $\Delta\epsilon = -14.2204 + 1.4896\sigma_L$	9–40	14
			Exponential: $\Delta\epsilon = e^{(2.1506 + 0.04184\sigma_L)}$	34–74	18
Kaneelhart	1.04	32,190	Linear: $\Delta\epsilon = -11.4044 + 0.7421\sigma_L$	15–50	13
			Exponential: =		

[1] $\Delta\epsilon$ = Creep during a 28-minute sustained-load period.
σ_L = Stress level, percentage of ultimate tensile strength.

strain was measured when the test specimen and the specimen with the compensating gage were rigidly held in a jig designed especially for this purpose.

The unloaded strains of some specimens did not remain constant but gradually changed with time. Exploratory measurements taken over a period of several months indicated that this drift of the unloaded strains took place at a constant rate. Consequently, for these specimens, the extrapolated portion of a linear regression of unloaded strain over time was used to estimate a base strain from which set could be measured.

The unloaded strain-time relationships for two specimens that were tested in stepwise fashion are shown in Fig. 1. This figure also illustrates the manner in which set progressively increased as each specimen was tested at successively higher levels of stress.

Results and Analysis

Results obtained in a previous investigation suggested that the relation of creep to stress level was most accurately described by a two-stage relationship consisting of a linear regression up to the threshold of set (the level of stress at which set first occurs) and a curvilinear regression thereafter (6). Subsequent results support the initial thesis of a multiple-stage relationship and, also, the proportionality of creep and stress level in the first stage.

Linear regressions of the form

$$\Delta\epsilon = a + b\sigma_L$$

and exponential regressions of the form

$$\Delta\epsilon = e^{(a + b\sigma_L)}$$

where: $\Delta\epsilon$ = creep during a 28-minute sustained-load period, microinches per inch,
σ_L = stress level, percentage of ultimate tensile strength,
a, b = constants, and
e = base of natural logarithms

were fitted by the method of least squares to the creep-stress level data of the eight species. The regression equations, the operative range of each equation, and the number of experimental values in fitting each equation are given in Table 1. Average values of specific gravity and ultimate tensile strength for each species are also given in this table.

The creep value, $\Delta\epsilon$, refers to the creep occurring between the second and 30th minute of the sustained-load period. At the higher stress levels, difficulty was encountered in maintaining a stable load during the first two minutes of test. This was due to the rapid rate at which the load had been applied and to the crushing of the specimens in the grips. The sensitivity of the gages was such that even small fluctuations in load caused significant fluctuations in strain measurements. Consequently the 28-minute sustained-load period, rather than the full 30-minute sustained-load period, was chosen as the creep time interval to obtain more accurate values of creep.

The results of stepwise loading tests on oak, basswood, cedro branco, and kaneelhart indicated that set began at approximately the same initial strain for all four species. This initial strain,

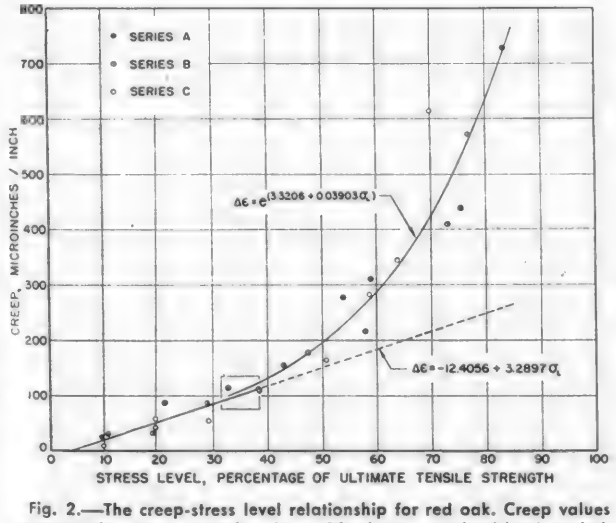

Fig. 2.—The creep-stress level relationship for red oak. Creep values represent the creep occurring in a 28-minute sustained-load period. Stress levels are expressed as a percentage of the average ultimate strength of each series. The rectangular area contains the experimental values considered in the fitting of both the linear and the exponential regressions and indicates the approximate boundary between the two stages of the relationship.

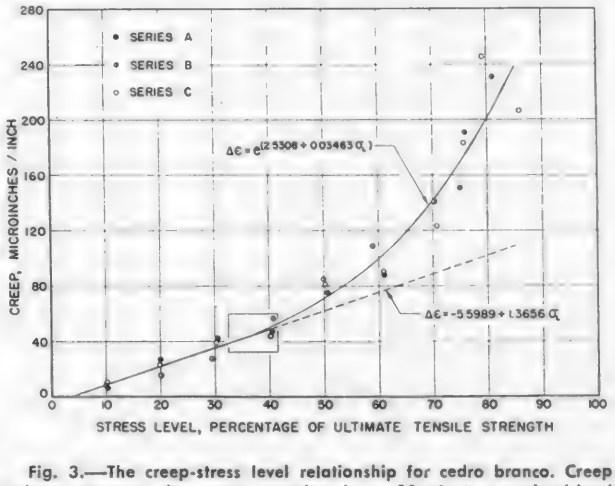

Fig. 3.—The creep-stress level relationship for cedro branco. Creep values represent the creep occurring in a 28-minute sustained-load period. Stress levels are expressed as a percentage of the average ultimate strength of each series. The rectangular area contains the experimental values considered in the fitting of both the linear and the exponential regressions and indicates the approximate boundary betweeen the two stages of the relationship.

Table 2.—MAXIMUM STRAIN AND CREEP AT THE 30 AND 60 PER CENT STRESS LEVELS FOR EACH OF EIGHT SPECIES

Species	Average maximum strain[1] microinches per inch	Creep[2] Thirty per cent stress level	Creep[2] Sixty per cent stress level
		microinches per inch	
Basswood	10,890	64	249
Cedro branco	10,080	35	100
Determa	8,420	36	104
Douglas-fir	7,420	17	46
Red oak	12,800	86	288
Angelique	9,120	21	68
Timbauba	10,340	36	106
Kaneelhart	7,470	11	33[3]

[1]Strain at failure not adjusted for previous set.
[2]Creep occurring in a 28-minute sustained-load period, values at 30 and 60 per cent stress levels calculated from the linear and exponential regressions respectively.
[3]Based on linear regression.

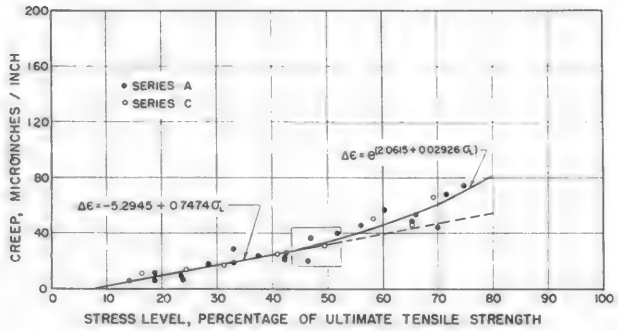
CREEP, MICROINCHES / INCH
STRESS LEVEL, PERCENTAGE OF ULTIMATE TENSILE STRENGTH
• SERIES A
○ SERIES C
Δε = e^(2.0615 + 0.02926 σ)
Δε = -5.2945 + 0.7474 σ

Fig. 4.—The creep-stress level relationship for Douglas-fir. Creep values represent the creep occurring in a 28-minute sustained-load period. Stress levels are expressed as a percentage of the average ultimate strength of each series. The rectangular area contains the experimental values considered in the fitting of both the linear and the exponential regressions and indicates the approximate boundary between the two stages of the relationship.

Table 3.—CREEP AND RECOVERY DATA FOR OAK, BASSWOOD, CEDRO BRANCO, AND KANEELHART SPECIMENS TESTED IN STEPWISE FASHION AT SUCCESSIVELY HIGHER STRESS LEVELS

Species	Specimen number	Stress level[1] per cent	Initial strain plus creep 0–2 min.	Creep 2–30 min.	Total set	Set per sustained load test
			microinches per inch			
Red oak	31	9.0	1020	9	0	0
		18.1	1920	28	0	0
		27.1	2810	58	0	0
		36.6	3810	103	20	20
		45.7	4550	146	67	47
		55.2	5970	232	166	99
		63.8	6890	269	277	111
		72.4	7800	380	429	152
Red oak	32	9.1	930	13	0	0
		18.2	1770	29	0	0
		27.4	2650	51	0	0
		36.5	3560	88	0	0
		45.6	4440	129	44	44
		55.6	5640	198	143	99
		64.3	6620	233	204	61
		73.0	7530	306	353	149
Basswood	15	11.4	1160	18	0	0
		22.8	2180	38	0	0
		45.7	4370	152	22	22
		57.1	5460	180	94	72
		69.2	6660	297	277	183
		80.6	7800	304	369	92
Basswood	16	11.5	1110	19	0	0
		22.9	2260	60	0	0
		34.4	3410	107	0	0
		45.9	4570	156	23	23
		57.3	5700	210	98	75
		68.8	6960	327	217	119
		80.3	8580	3530	571	354
Cedro branco	4	9.2	1140	8	0	0
		18.4	2080	21	0	0
		27.6	3050	36	0	0
		36.8	4120	48	0	0
		46.5	5150	74	16	16
		55.7	6140	109	32	16
		64.4	7420	145	64	32
		73.6	8540	201	168	104
Cedro branco	6	9.1	1120	4	0	0
		18.2	2110	15	0	0
		27.2	3120	34	0	0
		36.3	4140	39	16	16
		45.4	5120	54	54	38
		54.5	6140	82	117	63
		63.5	7480	129	246	129
		72.6	8580	151	419	173
Kaneelhart	6	10.0	720	0	0	0
		20.0	1380	2	0	0
		29.5	2010	3	0	0
		40.0	2820	17	0	0
		50.8	3580	22	0	0
		60.5	4270	20	13	13
		70.3	4960	32	52	39
		80.1	5620	41	116	64

[1]Stress level expressed as a percentage of the average ultimate strength of matched control specimens.

estimated to be 3300 microinches per inch, was used to determine the approximate boundary between the linear and exponential regressions. The creep-stress level values of specimens tested at initial strains greater than 3300 microinches per inch were considered in the fitting of the exponential regressions for each species. Experimental values at lower levels of strain were described with the linear regression. Where the experimental data were continuous, test values in the region of the threshold of set, which were included in the fitting of the exponential regression, were also considered in the fitting of the linear regression. The two regressions were not forced to intersect nor were they forced to be tangent at the threshold of set.

The linear and exponential regressions for red oak, cedro branco, and Douglas-fir are shown with the experimental observations in Figs. 2, 3, and 4. The creep-stress level regressions for the eight species investigated are shown in Fig. 5. It is apparent from this figure and from Table 1 that no definite correlation exists between the magnitude of the creep response and specific gravity. A significant correlation appears to exist between creep and maximum strain, however. Average maximum strain and creep at the 30 and 60 per cent stress levels are given for each species in Table 2. The relationship between these two variables is shown in Fig. 6.

The results of stepwise loading tests on oak, basswood, cedro branco, and kaneelhart were mentioned in describing the procedure used in fitting the linear and exponential regressions. Specimens of each of these species were tested at successively higher stress levels in order to investigate the rela-

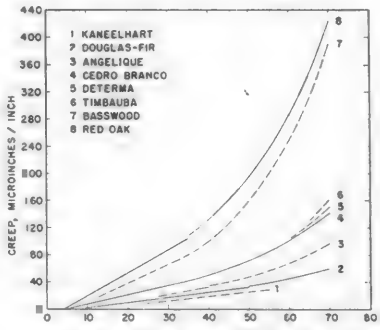

Fig. 5.—Creep-stress level regressions for eight domestic and tropical species. Creep values represent the creep occurring in a 28-minute sustained load period.

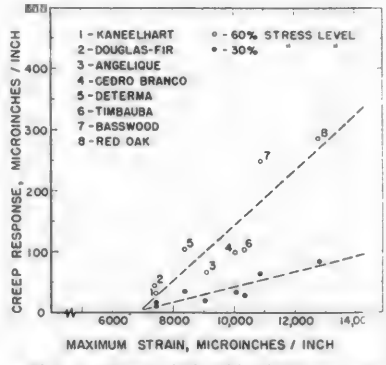

Fig. 6.—The relationship between creep at the 30 and 60 per cent stress levels and average maximum strain. Creep values represent the creep occurring in a 28-minute sustained-load period as calculated from the linear and exponential regressions for each species.

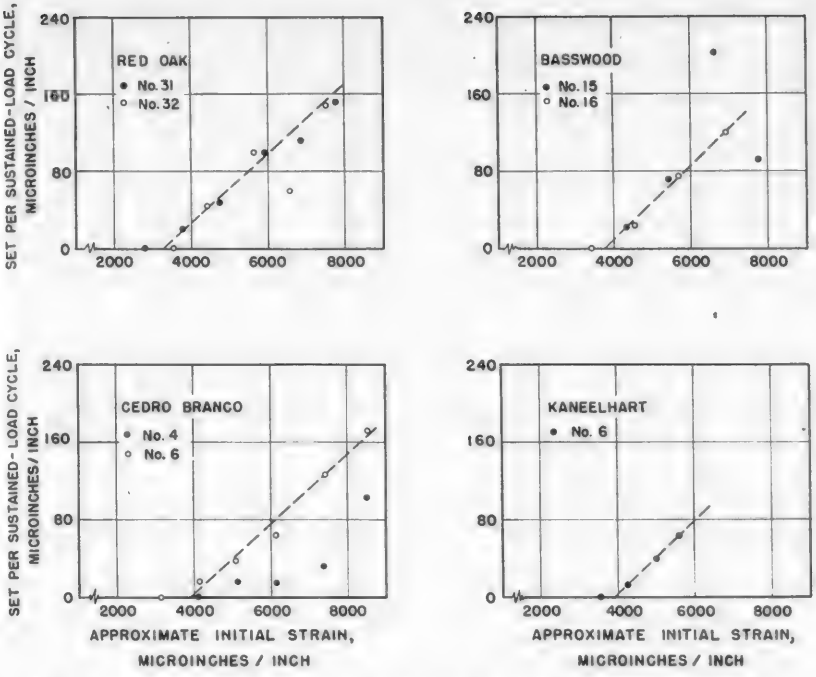

Fig. 7.—Set-approximate initial strain relationships for oak, basswood, cedro branco, and kaneelhart specimens tested in stepwise fashion at successively higher stress levels. Set values represent the difference between the unloaded strain measured at the end of the recovery period and the base strain. Approximate initial strain is equal to the initial strain plus the creep occurring in the first two minutes of the sustained load period.

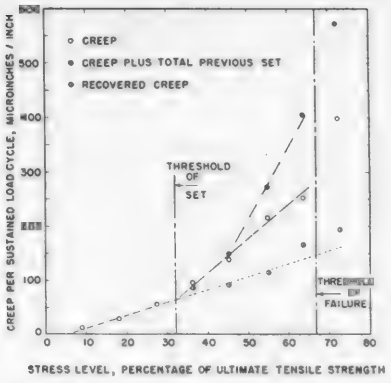
○ CREEP
• CREEP PLUS TOTAL PREVIOUS SET
• RECOVERED CREEP
THRESHOLD OF SET
CREEP PER SUSTAINED LOAD CYCLE, MICROINCHES / INCH
STRESS LEVEL, PERCENTAGE OF ULTIMATE TENSILE STRENGTH

Fig. 8.—Creep-set-stress level relationships for oak. Values shown are averages based on the results of two oak specimens tested in stepwise fashion at successively higher stress levels.

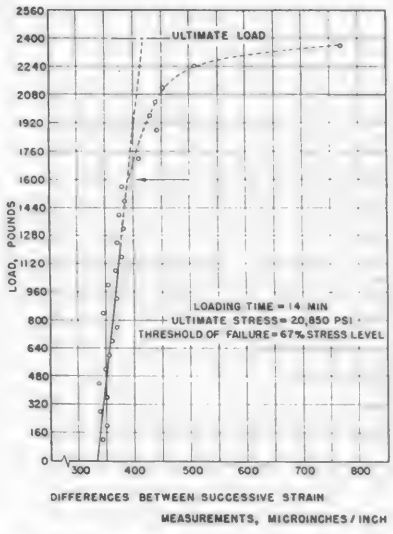
ULTIMATE LOAD
LOADING TIME = 14 MIN
ULTIMATE STRESS = 20,850 PSI
THRESHOLD OF FAILURE = 67% STRESS LEVEL
LOAD, POUNDS
DIFFERENCES BETWEEN SUCCESSIVE STRAIN MEASUREMENTS, MICROINCHES / INCH

Fig. 9.—Load-strain difference curve for an oak specimen tested statically to failure.

tionships between creep, set, and sustained stress. The sustained stress (in per cent), approximate initial strain, drift-corrected creep, total set, and set per sustained load test for each specimen are given in Table 3.

Columns three and seven of Table 3 indicate the approximate stress level at which permanent set first occurred in each specimen. The relationship between set per sustained-load test and approximate initial strain is shown in Fig. 7 for each specimen. The straight lines in this figure were fitted visually. These results indicate that set begins at approximately the same initial strain for the four species investigated, but that the stress level at which set occurs varies considerably. The results also seem to indicate that set, at each of successively higher stress levels, is proportional to initial strain.

Discussion

In general, the results obtained in this study confirm those of previous investigations. Minami (11), investigating the creep behavior of Sitka spruce and hinoki *(Chamaecyparis obtusa)* in tension parallel to the grain, observed creep at stress levels as low as 15 to 20 per cent of ultimate tensile strength. He also found that permanent set became apparent at about the 50 per cent level of stress.

Noticeable creep of Douglas-fir and white oak when stressed in tension parallel to the grain has been reported by Wood (15) at stresses as low as 1500 psi. Wood also reports that creep is approximately proportional to stress. On the other hand, Grossman and Kingston (4), studying the influence of stress on the creep of hoop pine, found that creep increased more than linearly with increasing stress, the greater part of this increase being due to irrecoverable strain.

It can be seen from Figs. 2, 3, and 4 that a linear regression will accurately describe the creep-stress level relation below the threshold of set. As the sustained stress is increased above this threshold point, set occurs and creep begins to increase at a more rapid rate. At the higher levels of stress, an exponential regression yields an adequate description of the data and also provides a satisfactory method for comparing the creep response of the different species.

Results of stepwise loading tests and static tests to failure, however, indicate that creep and level of stress may be related linearly above as well as below the threshold of set. Figs. 8 and 9 illustrate typical results obtained from these two types of tests. In Fig. 8, relationships are shown between creep, set, and stress level for oak specimens when tested at successively higher stress levels. The plotted values are averages based on the data given for this species in Table 3.

Fig. 9 shows load plotted against the differences between successive strain measurements for an oak specimen tested statically to failure. When inspecting the curve in Fig. 9 it should be kept in mind that differences between successive strain measurements of a material that behaves in strict accordance with Hooke's Law are constant up to the proportional limit. Therefore the load against strain-difference relation for such a material would appear as a vertical line within the region of proportionality.

It can be seen from Fig. 8 that, for a short distance above the threshold of set, creep, creep plus total previous set, and recovered creep appear to be proportional to stress level. Results indicate that in this region creep and set are directly related, and also that initial strain tends to be fully recoverable. This suggests that, above the threshold of set, a good description of the creep-stress level relation might be a second linear regression. The experi-

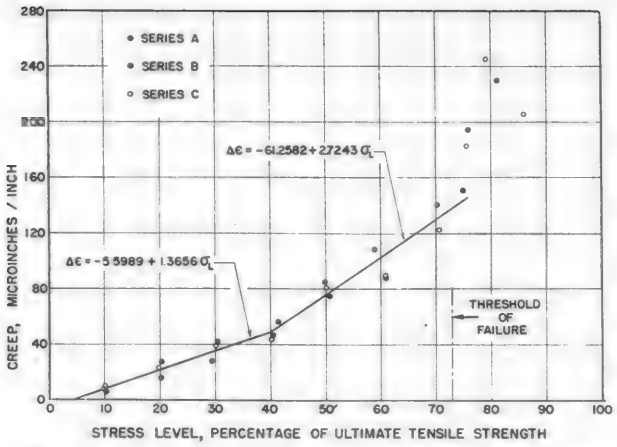

Fig. 10.—The creep-stress level relationship for cedro branco. Creep values represent the creep occurring in a 28-minute sustained-load period. Stress levels are expressed as a percentage of the average ultimate strength of each series. This figure illustrates the possibility of describing the creep-stress level relation above the threshold of set with a second linear regression.

mental observations shown in Fig. 8 also indicate this second linear regression may be operative only in a limited region. This restrictive condition is feasible. If there is some definite stress level, other than the threshold of set at which failure begins, it seems reasonable to expect that creep behavior would change as this threshold of failure was exceeded.

It can be seen from Fig. 9 that the load-strain difference curve departs from a linear relationship at about the 67 per cent stress level. Above this point the differences between successive strain measurements increase at an increasing rate until failure occurs. The 67 per cent stress level has been termed the threshold of failure for this particular oak specimen. This threshold value is shown in Fig. 8 as a vertical line. It can be seen from this figure that there was a more than linear increase in creep as the sustained stress was increased from 64 to 73 per cent of the ultimate tensile strength. The threshold of failure would seem to be a reasonable upper limit for a second linear regression.

The hypothesis that the creep-stress level relation below the threshold of failure can be described by two linear regressions, rather than a linear and a curvilinear function, was tested on the results for cedro branco. The linear regressions are shown with the experimental observations for this species in Fig. 10. The 73 per cent stress level value designated in Fig. 10 as the threshold of failure represents the average threshold, as determined from a load-strain difference curve, of four specimens tested statically to failure.

It is of interest to note that other high polymers exhibit distinct zones of strain behavior. In a study of the creep and recovery properties of viscose rayon yarn, Press (13) found that, below 0.75 per cent extension, recovery, though retarded, was complete. Press also reports that, between 0.75 and 4 per cent extension, complete recovery could only be attained by wetting and redrying; and that, above 4 per cent extension, the samples did not recover completely even after being reconditioned.

Ivanov (5) defines the point at which the load-strain difference curve, shown in Fig. 9, departs from a linear relationship as the lower limit of plastic flow. He maintains that this limit corresponds to the safe long-term strength.

In an earlier paper (6), the entire range of the creep-stress level relation was described with an exponential regression with a forced zero intercept. A linear regression was also fitted to the data at the lower levels of stress (5 to 30 per cent). By comparing the distribution of the experimental values around the two regressions, it was tentatively concluded that a two-stage relationship, consisting of a linear regression up to the threshold of set and a curvilinear regression thereafter, would be the most accurate description of the observed creep behavior.

Subsequent results support the initial thesis that creep and level of stress are proportional below the threshold of set. The additional evidence accumulated has made it possible to describe the creep-stress level relation in more specific terms than was possible with the general exponential regression with a forced zero intercept. In this report, the creep-stress level relations of the eight species investigated were described by means of a linear regression up to the threshold of set and an exponential regression thereafter.

Although the exponential regression gives an adequate description of the experimental data at the higher levels of stress, there is some indication that, for a limited range of stress above the threshold of set, the creep-stress level relation might be better described by a second linear regression.

More evidence is needed before any definite statements can be made regarding which of the regressions, the exponential or the second linear, would best describe creep behavior at the higher levels of stress. The exponential regression was emphasized in this paper because it is the more conservative of the two and also takes into account experimental values at the highest levels of stress.

Literature Cited

1. Armstrong, L. D. 1953. Short term creep tests on air-dry wooden beams. CSIRO, Div. of Forest Products, Australia. Project T. P. 16–1.
2. Dietz, A. G. H. 1949. Short-time creep tests on Douglas-fir. Proc. For. Prod. Res. Soc., 3: 352–360.
3. Ellwood, E. L. 1954. Properties of American beech in tension and compression perpendicular to the grain and their relation to drying. Yale Univ. School of Forestry Bull. No. 61.
4. Grossman, P. U. A., and R. S. T. Kingston: 1954. The influence of stress on creep. CSIRO, Div. of Forest Products. Australia. Project T. P. 16–2.
5. Ivanov, Yu. M. 1949. The new measure of the strength of wood and methods of its determination. Akademia nauk SSSR. Trudy instituta lesa, 4: 34–45. (Translated by H. P. Kipp, U. S. Forest Prod. Lab. Translation No. 201. 1954.)
6. King, E. G. Jr. 1957. Creep and other strain behavior of wood in tension parallel to the grain. Forest Prod. J. 7 (10): 324–330.
7. Kingston, R. S. T. 1949. Creep in initially green wooden beams. CSIRO, Div. of Forest Products, Australia. Project T. P. 16–1.
8. Kommers, W. J., and C. B. Norris. 1943. Plastic flow properties of two yellow birch plywood plates under constant shear stress. U. S. Forest Prod. Lab. Report No. 1324.
9. Lanza, G. 1909. Applied mechanics Ed. 9. Wiley, New York.
10. Minami, Y. 1953. Compressive creep tests on wood. Bulletin of the Faculty of Engineering, Yokohama National University, 2: 23–46.
11. Minami, Y. 1939. Tensile creep tests on wood. Jour. Aeronautical Res. Institute, 174: 23–27.
12. Minami, Y. 1935. Bending creep tests on wood. Jour. Aeronautical Res. Institute, 136: 1090–1102.
13. Press, J. J. 1943. Flow and recovery properties of viscose rayon yarn. Jour. of Applied Physics, 14: 224.
14. Tiemann, H. D. 1909. Some results of dead load bending tests by means of a recording deflectometer. Proc. ASTM 9: 534–548.
15. Wood, L. W. 1947. Behavior of wood under loading. Eng. News Record. 139 (24): 108–111.
16. Youngs, R. L. 1957. Mechanical properties of red oak related to drying. Forest Prod. J. 7 (10): 315–324.

CHEMICAL COMPOSITION OF

Cork from White Fir Bark[1]

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The cork fraction from white fir bark was found to consist primarily of a lignocellulosic network impregnated with a waxy ester and a complex polyphenol, both of which have potential commercial value. The chemical findings are also related to the biochemical process of suberization.

Bark is an important byproduct of the pulp, paper, and lumber industries. The largest use of bark is for fuel, although bark frequently may be a liability, since its disposal requires purchase and maintenance of waste burners. Previous reports from this laboratory have indicated bark of three western conifers—Douglas-fir, white fir (*Abies concolor* (Gord. and Glend.) Lindl.) and ponderosa pine—may be valuable for their extractive content (1, 2, 3).[3] These extractives consist primarily of wax, flavanoids, and tannin. Although these products are of potential value, they comprise only a small part of the total weight of the bark. Effective utilization, therefore, requires development of uses for the extractive-free residue.

Bark of two of these western species, Douglas-fir and white fir, contains from 20 to 50 per cent of a fraction that resembles commercial cork. This material appeared to be the most potentially valuable fraction of extracted bark residues, provided it could be effectively separated from the non-cork fraction of the bark. It would then be usable either directly as a commercial cork substitute, that is for crown seals and cork tile, or as a source of organic chemicals. The latter phase of development is the subject of this paper.

The objectives of this research were threefold:

- Development of a simple means of separating the cork fraction from whole bark;
- Characterization of components of the extractive-free cork fraction;
- Determination of types of chemical linkages present.

The last objective, though not of immediate practical consequence, was included since there is considerable disagreement in the literature as to the way in which cork components are chemically bound.

Previous chemical examination of the Douglas-fir cork fraction indicated it to be a rich source of saturated and unsaturated hydroxy fatty acids and complex polyphenols (4). It has been found subsequently that saturated hydroxy fatty acids (10), such as 9- or 12-hydroxy stearic acid, possess certain unique properties that may make them suitable as a raw material for synthetic, low-temperature lubricants (5, 6). The product currently used for this purpose, bis (2-ethylhexyl) sebacate, is derived from castor beans, which must be imported into this country. A substitute of domestic raw material is obviously desirable. This finding suggested that the chemical components of white fir bark also should be examined to determine whether the cork fraction might be a potential source of these acids.

Preparation of Cork

Separation: The following procedure was found to separate the cork completely from the remainder of the bark:

Freshly peeled white fir bark was hogged to pass a half-inch screen, and was then further reduced by a Rietz disintegrator or a Wiley mill. The air-dried, ground bark was then suspended in hot water (60° to 85° C.) and thoroughly agitated for about five minutes. During this time, the non-corky fraction became saturated and sank. The cork fraction, which remained afloat, was skimmed off the surface of the water and dried.

The temperature and duration of this operation reported here were optimum. Incomplete separation was obtained at temperatures below 60° C., while water at or near the boiling point eventually caused the cork fraction to sink. This method of separation also was applied to white fir bark residues remaining after removal of wax (benzene-extracted bark) or tan-

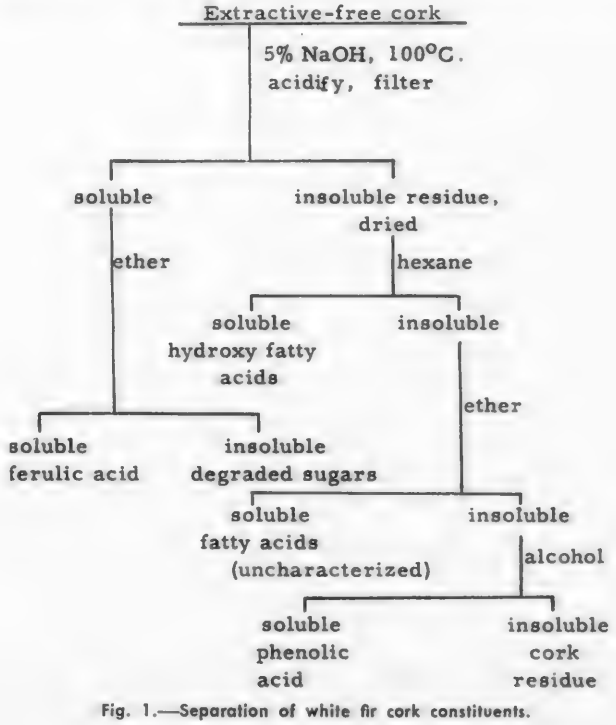


Fig. 1.—Separation of white fir cork constituents.

[1] A contributed paper (April, 1958) from the State of Oregon Forest Products Research Center.
[2] The author is now on the staff of the Olympic Research Division, Rayonier Inc.
[3] Numbers in parentheses refer to the Literature Cited.

nin (water-extracted bark). Good separation was obtained provided the bark was air-dried before flotation. The time that extracted bark remained in the flotation bath had to be extended to about 10 minutes. Based on this method, various samples of white fir bark were found to contain from 25 to 55 per cent cork, depending mainly on age and site of the tree.

When this procedure was applied to Douglas-fir bark, complete separation was not attained. Various grinding procedures were tried and temperature of the flotation bath was varied from 25° to 100° C., but a pure cork fraction could not be obtained. Attempts to separate cork from de-waxed or completely extracted whole Douglas-fir bark were similarly unsuccessful.

Extraction: In a previous study of whole white fir bark extractives (3), the most important extractives found were two benzene-soluble wax fractions, a hot-water-soluble phlobatannin, a hot-water or ether-soluble fraction containing d-catechin and l-epicatechin, both of which are isomeric 3, 3′, 4′, 5, 7-pentahydroxy flavanes, and an ethanol-soluble phlobaphene. Separate analyses of the cork and cork-free fractions of the bark indicated wax, flavonoids, and phlobaphenes are present principally in the cork, while tannins and carbohydrates are distributed about equally between the two fractions. To utilize white fir cork for crown seals, it appears necessary to remove the tannins, since they form highly colored reaction products with metal.

Extractive-free cork was prepared as follows: white fir bark (obtained through the courtesy of Weyerhaeuser Timber Company from a stand of trees in western Klamath County, Oregon, at an elevation of about 4,000 feet) was hogged and then extracted with an azeotropic mixture of methyl ethyl ketone and water (89% MEK) at or near the boiling point of the mixture. This solvent removes waxes, flavonoids, and most of the tannins and phlobaphenes. The extracted bark then was separated by flotation and extracted with hot water to remove carbohydrates and the remaining tannin. This procedure removed 97 per cent of the extractives.

Isolation of Hydroxy and Phenolic Acids from the Cork

The procedure devised for separation of extractive-free, white fir cork constituents varied somewhat from that previously used on Douglas-fir cork (4). The process outlined in Fig. 1 was essentially as follows: Extractive-free cork was saponified with aqueous caustic solution. This action resulted in a suspension of insoluble cork residue in a dark-colored solution of dissolved soaps of hydroxy and phenolic acids. The insoluble residue could not be separated readily by filtration or centrifuging, so the total mixture was acidified. The solids (precipitated acids and cork residue) then were easily filtered off and dried.

The dried solid material then was extracted successively with hexane, ethyl ether, and ethanol. The first two solvents removed various saturated and unsaturated hydroxy acid fractions, while ethanol removed the phenolic fraction. The residue remaining after extraction was primarily lignocellulosic in nature. Yields from laboratory determination are listed in Table 1.

Table 1.—COMPOSITION OF EXTRACTIVE-FREE WHITE FIR BARK

Fraction	Cork Per cent	Cork-free bark Per cent
Residue insoluble in hot 5% NaOH	32.1	66
Fraction removed with hot 5% NaOH	67.9	34
Water-soluble (after acidification)	6.4	18
Hexane-soluble	19.0	0
Ether-soluble	6.4	0.5
Alcohol-soluble	36.1	15.5

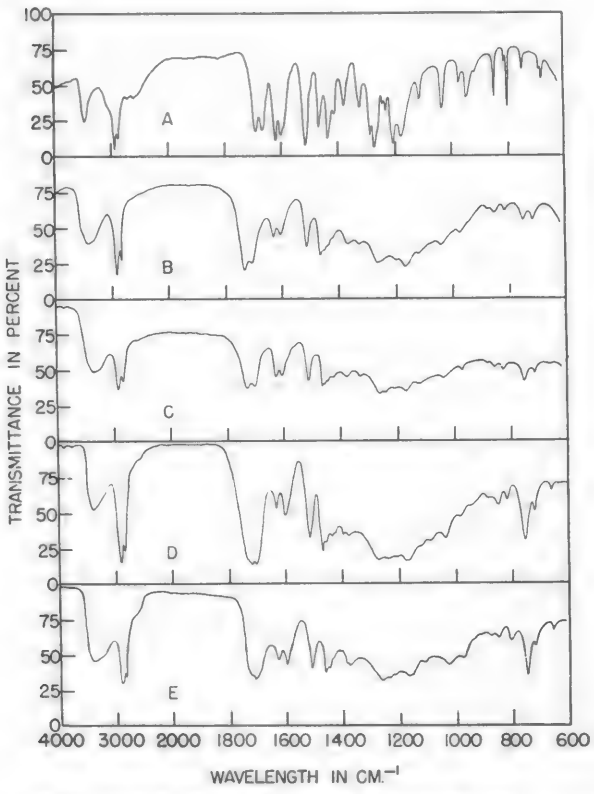


Fig. 2.—Infrared spectra of ferulic acid (A), white fir cork "suberin" isolated with dioxane-HCl (B), white fir benzene-soluble wax extractive (C), Mediterranean oak cork "suberin" isolated with dioxane-HCl (D), and Mediterranean oak cork benzene-soluble wax extractive (E).

Table 2.—COMPOSITION OF CARBOHYDRATES OF WHITE FIR BARK[1]

	Extractive-free cork Per cent	Caustic-insoluble cork residue Per cent	Extractive-free, cork-free bark Per cent
Insol. in 72% sulfuric acid	86.0	66.0	42.0
Hydrolyzed sugars			
Arabinose	1.8	1.5	2.3
Galactose	0.7	1.2	1.3
Xylose	0.9	2.8	5.1
Mannose	0.7	1.8	8.2
Glucose	6.9	18.3	31.7
Sum	97.0	91.6	90.6
Loss (by difference)	3.0	8.4	9.4

[1]Percentages based on oven-dry weight of fraction.

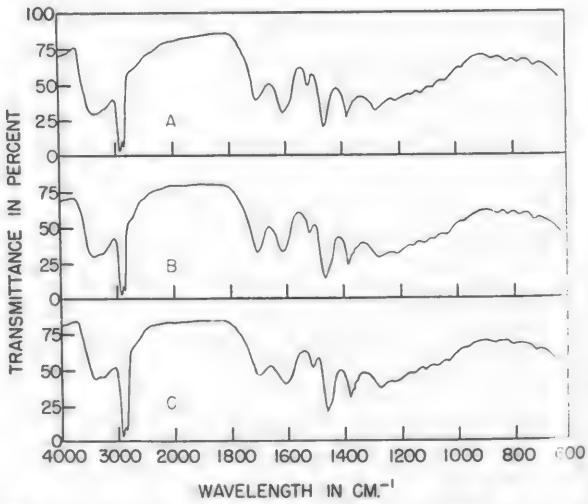


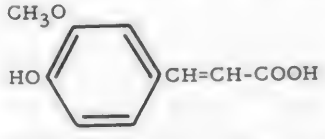
Fig. 3.—Infrared spectra of phenolic acid obtained by treating phlobaphene with caustic (A), phenolic acid from white fir cork (B), and phenolic acid from white fir benzene-soluble wax.

A large quantity of acids was prepared by treating 40-pound lots of cork with 200 pounds of water and 8 pounds of sodium hydroxide for each lot of cork. Live steam was introduced into the mixture for four hours. The saponification mixture was acidified with sulfuric acid and filtered through burlap sacking. The residue was air-dried and then extracted with ethyl ether and alcohol in a large stainless-steel Soxhlet-type extractor. The ether extract consisted of aliphatic acids, while the alcohol extract contained phenolic acids. The alcohol extract was concentrated to about 25 per cent total solids and poured into a large volume of 2 per cent sodium chloride solution. The precipitate of phenolic acids was filtered off, washed with water, and air-dried. The ether extract was evaporated to dryness and could be fractionated into a light-colored, hexane-soluble fraction and a dark, sticky, hexane-insoluble fraction.

The hexane-insoluble, benzene-soluble wax extractive had been shown previously (3) to yield an aliphatic hydroxy acid and an aromatic phenolic acid upon saponification. It appeared of interest to compare the constituents of this wax with those of extractive-free cork. Wax was saponified in the same manner as the cork to yield (based on the wax) 5 per cent unsaponifiables, 3 per cent water-soluble phenolic acids, 52 per cent hexane-soluble acids, 10 per cent ether-soluble acids, and 30 per cent ethanol-soluble phenolic acid.

Characterization of the Fractions

Water-soluble phenolic acid: Two-dimensional chromatography (organic phase of butanol-acetic acid-water, 4:1:5, one direction, and 2 per cent acetic acid in the other direction) (7) of the water-soluble fraction obtained from the saponification of cork gave an intense cerise spot at Rf of 0.84, 0.25, when sprayed with diazotized sulfanilic acid, and a similar but much weaker spot at Rf 0.84, 0.62. These spots correspond to *trans* and *cis* ferulic acid (I) respectively (8). Traces



of protocatechuic acid, vanillin, and vanillic acid also were noted on the chromatograms. These latter three phenols are obtained in small amount upon boiling ferulic acid in aqueous caustic solution, so it seemed likely that they were degradation products.

To confirm the chromatographic evidence, the water-soluble fraction was concentrated to about 5 per cent solids under vacuum and was liquid-liquid extracted with ether. The ether extract was evaporated to dryness, dissolved in boiling water, decolorized with charcoal, and placed in an icebox. In this way, light amber-colored crystals were obtained with melting point of 167–169° C. that was not depressed upon admixture with an authentic sample of ferulic acid. The infrared spectrum (paraffin mull) is shown in Fig. 2 and the ultraviolet spectrum in Fig. 4.

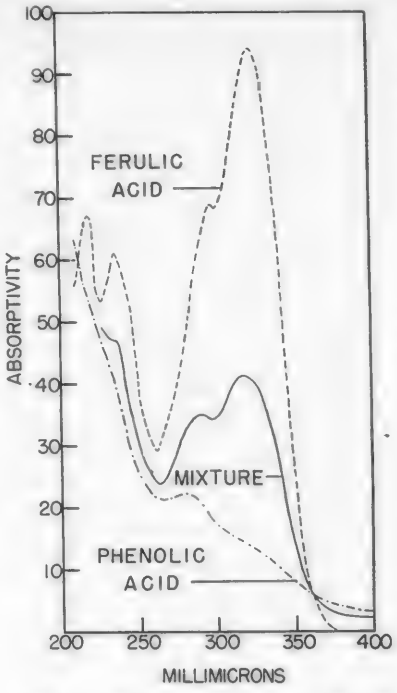


Fig. 4.—Ultraviolet spectra (in ethanol) of ferulic acid, cork phenolic acid, and a 2:1 mixture of phenolic acid and ferulic acid.

The water-soluble, phenolic fraction derived through saponification of the benzene-soluble wax extractive also was chromatographed and found to consist primarily of ferulic acid. Ferulic acid previously was found to be a constituent of Douglas-fir wax (1), but this is the first reported instance of ferulic acid as a plant cell-wall constituent. Re-examination of Douglas-fir bark showed that ferulic acid also was a constituent of the extractive-free cork of this species.

Phenolic acid: The phenolic acid fraction (as obtained by precipitation of an alcohol solution) was a reddish-brown powder. Elemental analysis indicated 60.22 per cent carbon, 5.74 per cent hydrogen, and 3.8 per cent methoxyl groups. The phenolic acid was very soluble in ethanol and methanol, moderately soluble in acetone and dioxane, and insoluble in water or ether. The acid could be dissolved in cold 10 per cent sodium bicarbonate, 5 per cent sodium carbonate, or 1 per cent sodium hydroxide solutions. This finding indicated the presence of a carboxylic function. When an alcoholic solution was treated with a 1 per cent ferric chloride reagent, a greenish-black precipitate was obtained.

The phenolic acid fraction obtained from the benzene-soluble wax extractive had physical and chemical properties similar to those of the phenolic acid obtained from extractive-free cork. It was a light-brown, amorphous solid, soluble in ethanol, methanol, or acetone, and insoluble in ether or water. A greenish-black precipitate was obtained upon treatment with ferric chloride reagent. Elemental analyses indicated 62.8 per cent carbon, 5.5 per cent hydrogen, and 2.6 per cent methoxyl. Further evidence for the identity of these products was found in a comparison of the infrared spectra of the products and their methylated derivatives (prepared by the dimethyl sulfate-anhydrous potassium carbonate-acetone method).

The ultraviolet spectrum (Fig. 4) and the infrared spectrum (Fig. 2) of phenolic acids from the cork and the wax extractive closely resembled that of white fir phlobaphene and tannin except for the presence of unconjugated carboxy groups (absorption band at 1700–1705 cm^{-1}) in the phenolic acid. The speectral comparisons suggested that the cork and the wax phenolic acids were essentially phlobaphene in which carboxyl groups either were introduced during the isolation procedure or, less likely, were formed in place through enzymatic or air oxidation. Slight, but significant, methoxyl content suggested that the phenolic acid was contaminated with, or contained, lignin as a copolymer. Absence of infrared absorption bands attributable to conjugated double bonds indicated the phenolic acid was not a degradation product of ferulic acid. An extensive study of white fir phenolic acid subsequently has been made in this laboratory by M. Fahey and has been reported separately (9).

Hydroxy acids: The hexane-soluble fraction was a light-yellow to cream-colored fraction that melted at 72° C. It was separated into three fractions by taking cuts as the total saponified residue was being extracted with hexane in a Soxhlet extractor. Each fraction represented roughly a third of the material. The first fraction contained acids most soluble in hexane, while the third contained acids least soluble in hexane. Each fraction (5 g.) was refluxed for 2.5 hours in 100 ml. of 5 per cent sodium hydroxide solution. The soap solutions were acidified with sulfuric acid and immediately filtered to remove precipitated acids.

Fraction 1 acids were dissolved in hot ethyl acetate. The precipitate obtained upon cooling melted at 83°–84° C. and had an average neutral equivalent of 330. The calculated neutral equivalent for hydroxy arachidic acid, $C_{20}H_{40}O_3$, is 328. The mother liquor was diluted with a little hexane. This dilution gave a large amount of a second fraction, m.p. 80° C., neutral equivalent 244. The calculated value for monohydroxy myristic acid is 244.3. The infrared spectrum was identical with that of hydroxy myristic acid from the hexane-insoluble, benzene-soluble wax of white fir bark (4).

Fraction 2 acids were recrystallized several times from ethyl acetate. This fraction melted at 84°–85° C. and had a neutral equivalent of 254.5.

Fraction 3 acids were obtained as two fractions by fractional crystallization from ethyl acetate. The least soluble fraction melted at 92° C. Upon methylation with dimethyl sulfate and KOH, an acid was obtained with a melting point of 108°–109° C. and a neutral equivalent of 178. Elemental analysis indicated 69.39 per cent carbon and 10.97 per cent hydrogen. The more soluble fraction obtained by ethyl acetate crystallization was identical to that obtained in fraction 2 above.

A different type of fractionization also was attempted. This type involved methylation of the whole hexane-soluble fraction. Eleven grams of the hexane-soluble acids were methylated with dimethyl sulfate and aqueous potassium hydroxide. The methylated acids (only the aliphatic hydroxyl function was methylated by this treatment) were dissolved in ethyl acetate (100 ml.). A crystalline precipitate was obtained (1.6 g.), which, after recrystallization from acetone, melted at 83°–84° C. and had a neutral equivalent of 325. When hexane (20 ml.) was added to the ethyl acetate mother liquor, 8.8 g. of solids were obtained, with melting point at 74° C., and neutral equivalent of 215.

The experiments indicated at least three acids were present in the hexane-soluble fraction. One of them comprised about 85 per cent of the extract and appeared to be a monohydroxy myristic acid identical with 13-hydroxy myristic acid present in the hexane-insoluble wax extractive (3). Two other acids were present—one was probably a hydroxy arachidic acid and the other possibly a dihydroxy dicarboxylic acid, such as is found in commercial Mediterranean oak cork. It was apparent the separation was not complete. To characterize these acids completely, the procedure of Jensen (10) may be applicable. This procedure involves methylation with diazomethane, chromatography on alumina, and characterization of the eluted (methyl ester) fractions.

Insoluble cork residue: The insoluble cork residue remaining after saponification was washed with alcohol and water. A Klason lignin determination on the dried residue indicated 66 per cent "lignin" based on the residue, or 21 per cent based on extractive-free cork. That the cork contained lignin was suggested not only by a positive phloroglucinol/HCl color reaction for lignin given by the original, extractive-free cork fraction, but also by the following experiment: Caustic-insoluble cork residue was placed in a tall alundum crucible and extracted for four hours with dioxane containing 1 per cent concentrated hydrochloric acid. The dioxane extract was evaporated to a small volume and poured into water. The precipitate was filtered off, washed, dried, redissolved in dioxane, and precipitated into ether. The ether-insoluble product was light-tan, and gave a magenta coloration with phloroglucinol/HCl. The product contained 14.5 per cent methoxyl. The infrared spectrum was compared with dioxane-HCl lignin obtained from white fir wood in the same manner. Similarity of the spectra indicated the product from the cork either is closely related to or is identical with wood lignin.

To characterize the carbohydrate portion of the bark, hydrolyzates from the 72 per cent sulfuric acid "lignin" determination of extractive-free cork and the caustic-insoluble cork fraction were submitted to quantitative paper chromatography. Results (see Table 2) indicated some carbohydrates were removed by the caustic treatment, and the carbohydrates of the caustic-insoluble cork fraction was primarily cellulosic, since the principal sugar obtained upon hydrolysis was glucose. Corresponding analysis of the carbohydrates of cork-free, extractive-free white fir bark indicated a similar ratio of sugars in the cork and non-cork fractions of the bark. The amount of carbohydrates in the latter fraction was appreciably higher, however.

Constitution of Extractive-free Cork

The following experiment indicated the manner in which phenolic acid, ferulic acid, and hydroxy fatty acids are linked in the extractive-free cork residue: Extractive-free cork was placed in a tall alundum crucible and extracted for six hours in a Soxhlet extractor with dioxane containing 1 per cent concentrated hydrochloric acid by volume. The dioxane extract was concentrated and poured into water. The precipitate was centrifuged, washed with several portions of water, and then dried. Extraction of the dried precipitate with chloroform or benzene gave a brown wax, softening point 70° C., in 48 per cent yield based on the original extractive-free cork. The wax was not soluble in hexane. Saponification of the wax with hot 5 per cent caustic solution gave 72 per cent hydroxy aliphatic acids, 6 per cent ferulic and other water-soluble acids and 22 per cent phenolic acid. Physical and chemical properties closely resembled those of the hexane-insoluble, benzene-soluble wax originally extracted from the cork. Comparison of the ultraviolet (Fig. 5) and the infrared spectra of the two products (Fig. 2) further indicated their similarity. Absence of an absorption band at 1750–1765 cm.$^{-1}$ indicated esters of phenolic groups were absent. Presence of bands at 1735 and 1740 cm.$^{-1}$ indicated esterification was primarily through alcoholic groups; that is, carboxyl groups of the hydroxy acids were esterified to aliphatic hydroxyl groups of the phenolic acid, and probably some of the hydroxy acids were joined to each other in polyestolide-type linkages. The ultraviolet spectrum of the waxy esters is virtually identical with that of a mixture of ferulic acid and phenolic acid (compare Figs. 4 and 5).

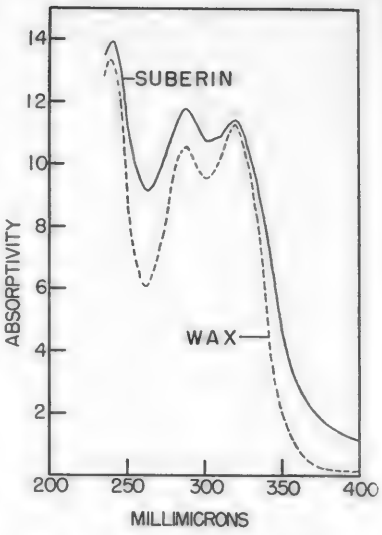
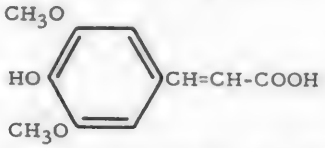


Fig. 5.—Ultraviolet spectra (in chloroform) of white fir cork "suberin" isolated with dioxane-HCl, and white fir benzene soluble wax extractive.

Isolation of this dioxane/HCl wax from extractive-free cork indicated hydroxy and phenolic acids were esterified in the cell wall of the cork. The cork may therefore be considered a lignocellulose network impregnated with a hydroxy-phenolic acid ester. Although this ester cannot be removed by neutral solvents, addition of mineral acid to polar solvents such as ketones or alcohols as well as dioxane,

allows extraction of this material. The most efficient solvent system was found to be methyl cellosolve containing 2 per cent concentrated hydrochloric acid.

It appeared of interest to determine whether hydroxy acids present in extractive-free Mediterranean oak cork (the cork of commerce) also were esterified to a phenolic residue. Commercial cork, therefore, was extracted with benzene, alcohol, and water and then was treated with dioxane-HC1. The dioxane-HC1 extract was precipitated with water and then extracted with benzene. In this way, a brown wax was obtained in about 55 per cent yield. Saponification yielded aliphatic, saturated and unsaturated hydroxy acids (65 per cent), a water-insoluble phenolic acid (described by others as "cork lignin", or phlobaphene) in 30 per cent yield, and 5 per cent of a water-soluble fraction that showed the presence of sinapic acid (II) by paper chromatography (11).



To confirm the presence of this compound, 200 g. of extractive-free oak cork was saponified according to the procedure described for white fir cork. The water-soluble phenolic acid fraction was extracted with a large volume of ether, the ether was evaporated to dryness, and the residue was taken up in boiling water, decolorized with charcoal, and then placed in an icebox. Pale-yellow crystals (50 mg.) were obtained, m.p. 190° C. (lit., 192° C.). Color reactions and chromatographic Rf were identical with those reported for sinapic acid.

The benzene-soluble extractive of commercial cork was suspended in a small volume of warm acetone. The mixture was cooled and filtered to remove the crystalline pentacyclic triterpenoids, cerin and friedelin. The filtrate was evaporated to dryness to give a light-tan wax, m.p. 67°–70° C. Comparison of the infrared spectrum (film from chloroform) of this fraction with that of the brown wax obtained by dioxane-HC1 extraction of extractive-free oak cork indicated identity. It appears, therefore, that the chemical nature of commercial cork is similar to that of white fir and Douglas-fir cork; that is, a lignocellulose network impregnated with a phenolic-hydroxy acid ester.

Discussion

Several products isolated from white fir cork appear to have commercial utility. The phenolic acid fraction has been investigated in this laboratory by J. Mater and found to be suitable as a partial substitute for phenol or resorcinol in phenol-formaldehyde resins. The hydroxy-fatty acid fraction can be readily recrystallized to yield a nearly pure 13-hydroxy acid fraction. Although di-esters of this product have not yet been prepared, the similarity of this product to hydroxy stearic acid indicates that it may be suitable as a raw material for low-temperature lubricants. Further testing needs to be done to establish this, however. The waxy ester, isolable by solvents containing hydrochloric acid, may serve as a vegetable wax replacement.

The botanical implications of the findings in this report also merit discussion. A protective layer known as the periderm (12) covers old stems and roots of most woody plants. The outer layer of cells, the phellem or, more simply, cork, is thick enough to constitute a major portion of the bark in some species of trees. Botanists describe cork tissues as being "suberized" or impregnated with a material called "suberin." A search of botanical literature fails to reveal a really adequate definition of the substance known as suberin, other than that it is a waxy material deposited in the cell-wall of cork which serves to waterproof the cells and is not removable by inert solvents. Previous research on commercial oak cork (13), birch cork (14) and sycamore, pine and fir bark (15) has shown that hydroxy fatty acids may be obtained readily through saponification of extractive-free cork or whole bark. This circumstance has led some investigators to suggest that suberin is a high-molecular ester of various fatty acids (16); that is, a polyestiolide.

In this paper, evidence has been presented to show that fatty acids in the cork cell wall are removable as a "wax" in which they are combined with polyphenols or phenolic acids. If suberin is to be defined botanically as the substance that impregnates and waterproofs the cellulosic cork cell wall, then, chemically, suberin should be defined as a hydroxy fatty-phenolic acid ester. It appears that, in gymnosperm cork, the hydroxy fatty acids are of relatively low molecular weight, and the phenolic portion consists of a complex polyphenol, apparently related to the phlobaphene, and a simple phenolic acid, ferulic acid. In angiosperm cork, it appears that the hydroxy fatty acids are of increased molecular weight, and the phenolic portion consists of a polyphenol of presently unknown constitution and a simple phenolic acid, sinapic acid. The results reported in this paper for three woody species suggested that, although the chemical structure of individual components of the suberin ester may vary with species, the general chemical nature of suberin will be independent of species.

Conclusions

Chemical analyses of white fir cork indicated the following composition (oven-dry basis): 26.0 per cent extractives (wax, catechin, epicatechin, tannin, phlobaphene, and carbohydrates); 18.8 per cent hydroxy fatty acids (hydroxy myristic acid, hydroxy arachidic acid, and others); 26.7 per cent phenolic acid (a complex polyphenol closely resembling the phlobaphene present in the extractive fraction); 4.7 per cent low-molecular-weight phenols (principally ferulic acid); 8.2 per cent cell-wall carbohydrates (probably cellulosic since glucose is the main sugar obtained upon acid hydrolysis); and 15.6 per cent "lignin".

Presence of considerable amounts of hydroxy fatty acids in the cork fraction of white fir bark and discovery of a simple means of separating the cork fraction from whole bark indicated that the cork is a potentially valuable raw material. Considerable work remains to be done on composition and properties of cork acids and soaps before their value as low-temperature lubricants can be established. It is hoped this preliminary report will stimulate subsequent work in that direction.

Literature Cited

1. Kurth, E. 1951. J. Forest Prod. Research Soc. I: 98.
2. Kurth, E., and J. Hubbard. 1951. Indus. & Eng. Chem. 43: 896.
3. Hergert, H., and E. Kurth. 1953. Tappi 36: 137; J. Org. Chem. 18: 521.
4. Hergert, H., and E. Kurth. 1952. Tappi 35: 59.
5. Teeter, H., L. Gast, E. Bell, and J. Cowan. 1953. Indus. & Eng. Chem. 45: 1777.
6. Gast, L., C. Groston, W. Schneider, and H. Teeter. 1954. Indus. & Eng. Chem. 46: 2205.
7. Roberts, E., and Wood. 1953. Biochem. J. 53: 352.
8. Williams, A. H. 1955. Chem. and Indus. 120.
9. Fahey, M., and E. Kurth. 1957. Tappi 40: 506.
10. Jensen, W. 1950. Paper and Timber (Finland) 32: 261, 291.
11. Bate-Smith, E. C. 1956. Proc. Royal Dublin Soc. 27: 165.
12. Eames, A. J., and L. H. MacDaniels. 1947. Introduction to Plant Anatomy, 2nd edition. McGraw-Hill, New York, p. 248.
13. Cooke, G. 1942. Cork and Cork Products, Crown Cork and Seal Co., 30 pp.
14. Jensen, W., and R. Ostman. 1954. Paper and Timber (Finland) 36: 427.
15. Sharkov, W., V. Kalnina, and S. Sobetskii. 1939. Lesokhim. Prom. No. 5, 8; (Chem. Abs. 1940, 34: 5273.)
16. Ribas, I. 1942. Ion 2, No. 6, 25.

COLORIMETRIC DETERMINATION OF Creosote in Old Poles

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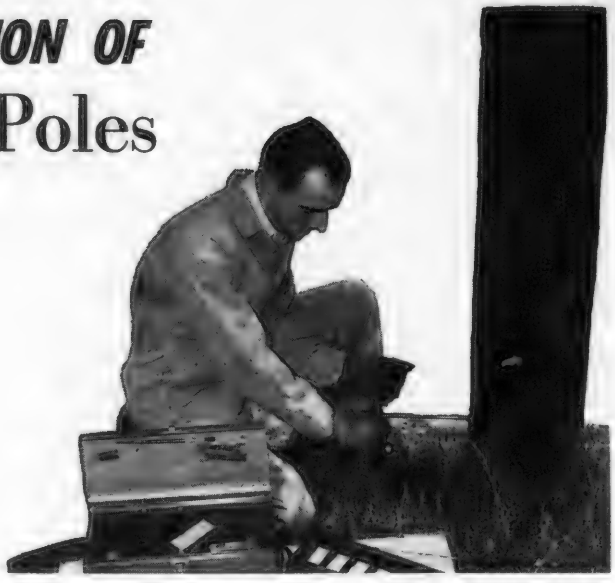


An accurate quick test to determine how much creosote is left in old poles would greatly simplify maintenance problems for utility companies. Though refinements are needed, this method shows promise.

IT HAS BEEN ONLY ABOUT 30 years since the large-scale use of creosoted wood poles became a uniform practice with power transmission and communications companies in this country. The average useful life of creosote poles treated by the procedures employed during the last 30 years has been estimated to be about 35 years, so that the oldest of these large installations are now nearing the age when many of the poles must be replaced?

For this reason, many pole-using companies have set up pole-line inspection procedures that are started after a given group of poles have been in service for 15 or 20 years. This inspection is directed toward determining the physical soundness of the poles at the time, but affords no means of estimating how many years of life remain for the poles that are judged fit for further service.

The question of fitness for further service also arises when poles must be removed for line changes; for example, to widen streets or highways, or for other reasons. Because the cost of installation represents much of the cost of a pole in service, a mistake in judging whether or not it should be re-used can be costly. On the other hand, it would also be costly to throw away a pole that contains sufficient creosote to provide protection for it over a period of many more years of service.

The Author: Monie Hudson holds a MS degree from the University of Wisconsin. He was research director for Taylor–Colquitt for 14 years, and holds patents on vapor drying and solvent recovery processes.

Colorimetric Method Procedure

These considerations led to the development, in 1954, of a rapid means for determining the amount of creosote in old poles.[1, 2] This method utilizes the apparatus shown in Fig. 1. In carrying out the test, a cylindrical core of wood is removed from the pole to be tested by means of the hollow borer, *A*. The whole boring or a known length of any section of the boring may be used for the test, depending on whether the colorimetric standards are made up for whole borings or for certain sections of borings. In the present work, ½-inch sections of borings were used.

In any case, the extreme outer end of the boring, the outer 1/32 inch is first cut off and discarded to eliminate any tarry deposits from the surface that would give erroneous results. The boring obtained is inserted into the tube *B*, where it is forced by a rod against a high-speed grinding wheel connected with the motor shown. The wood, reduced to fiber by the grinding action, drops into the glass test tube *C*. A solvent, dimethylformamide (DMF), is added to the tube to fill it to a graduated mark.

When the tube is stoppered and shaken, the solvent dissolves the creosote from the wood to form a brown solution. The tube containing this solution is then inserted in the color comparison block *D*. The amount of creosote in the pole being tested is determined by matching the solution obtained from the ground-up boring with the color of standard solutions containing known amounts of creosote. These standard solutions are kept in sealed tubes, which are fixed in the block *D* below the numbers 2, 4, 6, and 8. These numbers indicate the number of pounds of creosote there are per cubic foot of wood in the pole being tested.

The results of colorimetric tests on borings obtained from old creosoted southern pine poles that had been removed from lines of two power companies are reported here.

To begin this work, it was arbitrarily decided to proceed on the sweeping assumption that creosote extracted from old poles might yield the same color at a given concentration, regardless of creosote type, age of the poles, position from which the borings were taken—that is, whether below the groundline, at the groundline, or above the groundline—and regardless of the cross-section, from surface to center of the poles, from which the borings were taken.

The pole selected for a standard was southern yellow pine treated with 10 pounds of creosote per cubic foot in 1940. The outer circumferential inch of a two-foot section about six feet above the groundline was reduced to sawdust, and this sawdust was extracted with cold dimethylformamide (DMF). The extract was filtered and reserved as a stock solution from which to prepare color standards. The amount of creosote in this stock solution was determined on a sample by

[1] Hudson, M. S. 1955. Determining creosote in standing poles. Telephony, Nov. 26.

[2] Rawls, J. A., and Hudson, M. S. 1955. Pole line inspection and its increasing importance. Conf. paper 55–554, AIEE.

Fig. 1.—The equipment kit for determining creosote colorimetrically.

distilling off the DMF through a 10-inch Hempel fractionating column. The residue was considered to be creosote.

The following data were used as a basis for preparing standard color-comparison tubes:

1. Diameter of the borings taken from the poles was 0.177 inch.
2. Length of boring used in tests was ½ inch.
3. For the ½-inch section of boring, 0.0032 gram of creosote corresponded to 1 pound per cubic foot. To obtain 0.0032 gram of creosote, it was necessary to use 0.064 gram of the stock solution since it contained 5.1 per cent of creosote.

Series of standards were prepared by first making up 100 ml of a strong solution. A convenient solution was one in which the amount of creosote in 10 ml corresponded to 20 pounds per cubic foot in a ½-inch section of boring. An appropriate amount of this strong solution was diluted with DMF to give 10 ml of a solution of desired concentration. In this way, series could be made up of standards corresponding to 1, 2, 3, 4, and so on pounds of creosote per cubic foot.

It was found that tubes containing creosote equivalent to 20 pounds per cubic foot could be differentiated in 1 pound per cubic foot intervals, while at 8 pounds per cubic foot, differentiation was possible at ½ pound differences.

In making comparisons of extracts from boring samples that had just been ground up and shaken, it was also necessary to include in the standards the same amount of ground-up untreated wood as was contained in the unknown being tested. A more satisfactory way of doing this, however, was found to be to filter the wood from the solution containing the ground-up boring and then compare the optically clear solution with standards made up without adding ground-up wood.

With this basic procedure established for the preparation of colorimetric standards, the next step was to devise a means of checking the results obtained with it in order to study the effects of the numerous variables that had been ignored in the beginning.

The Semi-Micro Extraction Method

Because it was known that the conventional hot toluene extraction method used for the determination of creosote in treated wood would be subject to gross inaccuracies if attempted on single borings or on ½-inch sections of borings, it was necessary to develop a special procedure for determining the amount of creosote in such a small sample. The procedure developed was as follows:

A boring was taken as described above in connection with the colorimetric method. It was ground to fiber in the grinding device described, and the fiber was collected in a small weighing bottle. The weighing bottle was then placed in a dessicator over a saturated aqueous solution of calcium nitrate, where it was allowed to remain overnight. The humidity of air over such a calcium nitrate solution is 51 per cent, and wood comes to an equilibrium moisture content of 8 per cent in this atmosphere.

After this equalizing step, the wood was weighed in the weighing bottle, and 5 ml of DMF were added to it. It was then allowed to sit for 2 hours, after which the solution was filtered with a micro-Buchner funnel and the wood in the weighing bottle and on the filter was washed with a total of 5 ml of DMF in three portions. The filter was then allowed to suck dry. The filtrate was reserved in a clean, stoppered test tube for comparison with the colorimetric standards described above. The wood was then washed with a total of 20 ml of acetone in three portions, after which any wood that had been transferred to the filter paper by the washing operation was returned to the weighing bottle by brushing it from the filter with a camel-hair brush. The weighing bottle containing the wood was then oven dried for one hour at 100–105° C. The weighing bottle containing the extracted, oven-dried wood was re-weighed.

The method used for calculation of the amount of creosote contained in the boring was based on the assumption that the sample after equalization over a calcium nitrate solution had come to a moisture content of 8 per cent (which by tests on known amounts of water and wood was shown to be valid) and that the total loss in weight upon extraction and oven drying was made up of water and creosote. A weight equivalent to 8 per cent of the oven-dry weight of the sample was deducted from this total loss in weight to give the amount of creosote extracted. An example of this calculation follows:

Sample of ground-up boring weighed initially 0.120 gm
Sample after equilization over saturated $Ca(NO_3)_2$ solution weighed 0.105 "
Sample after extracting with DMF and oven drying weighed 0.085 "

(0.105–0.085) = 0.020 gm. composed of creosote extracted plus 8% water based on oven-dry wood weight

$0.020 - (0.085 \times .08) =$ 0.013 gm creosote

$$\frac{0.013}{0.085} \times 100 = 15.3\% \text{ creosote}$$

Creosote in terms of pounds per cu. ft. of wood was obtained by multiplying the per cent of creosote found by 32, which is the average weight per cubic foot of oven-dry southern yellow pine based on the green volume:

$32 \times 0.153 = 4.9$ lbs. of creosote per cubic foot

In the discussion that follows, this gravimetric method is called the semi-micro extraction method.

Comparison of Colorimetric and Semi-Micro Results

In Table 1 are shown the results obtained by the colorimetric method and by the semi-micro extraction method. The upper part of the table shows the results obtained with eight borings taken at the same level in the poles, two borings being taken at points 90° apart around the poles. The outer half inch of these borings was run by the semi-micro extraction method and the 10 ml of extract obtained was compared with the standard color tubes to obtain the values shown under the column headed "By color standard". The sets of eight borings were taken from each pole at three feet below the groundline, at the groundline, and about six feet above the groundline.

The data in the lower parts of the table show the averages for four borings, one at each of the 90° spacings around the pole for the second half inch and for the third half inch. The figures in Table 1 are given to show something of the variations in creosote content around the pole at any given level and at three different levels in the pole.

The average figures for each of the poles in Table 1 are shown plotted in Fig. 2. Comparison of these sets of curves shows that, for poles 1 and 2, and color standards made from the arbitrarily selected 1940 pole gave results that agree within about 1 pound per cubic foot of those found by the semi-micro extraction method. Pole number 3 indicates by the color standards that it, however, contained only about one half the amount of creosote that was found by semi-micro extraction.

In each of the sets of curves, it should be noted that there is a marked similarity between the pattern made by the BGL, GL, and AGL curves for data determined by the two different methods. This indicates that there is a definite relationship between amount of creosote in the borings and the depth of color of the extracts. The curves for poles 2 and 3 show the tendency of creosote to concentrate at the groundline, which has been reported previously by other workers.[8]

Table 2 contains data obtained by

[8] Andrews, J. W., S. N. Buco, and P. O'Brien. 1955. Distribution and composition of creosote in a pole that has been in service 25 years. Proc. AWPA, 51: 66.

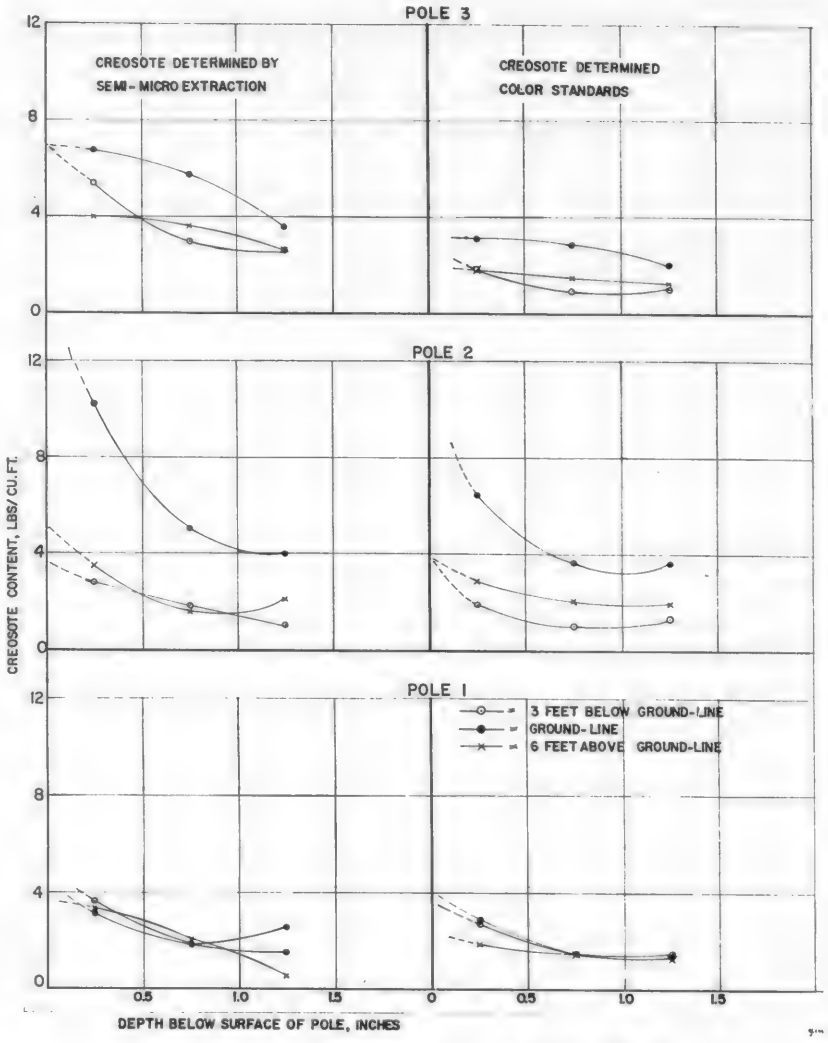


Fig. 2.—Creosote distribution in three old southern pine poles.

Table 1.—EXTRACTION OF THREE OLD CREOSOTED SOUTHERN PINE POLES WITH COLD DIMETHYLFORMAMIDE

Pole No.	ZONE FROM WHICH BORINGS WERE TAKEN: No. of borings	3 Feet Below Groundline: Grams O.D. Wood	Creosote: By semi-micro extraction grams	Creosote: By semi-micro extraction lbs/cu. ft.	Creosote: By color standard lbs/cu. ft.	Groundline: Grams O.D. Wood	Creosote: By semi-micro extraction grams	Creosote: By semi-micro extraction lbs/cu. ft.	Creosote: By color standard lbs/cu. ft.	Above Groundline: Grams O.D. Wood	Creosote: By semi-micro extraction grams	Creosote: By semi-micro extraction lbs/cu. ft.	Creosote: By color standard lbs/cu. ft.	Description of Pole
Outer ½ Inch														
1	8	0.106	0.012	3.7	2.7	0.108	0.010	3.1	2.9	0.112	0.011	3.3	1.9	Creosoted in 1931, 8 lbs/cu. f. Removed 1955, line change
2	8	.103	.009	2.8	1.9	.106	.033	10.2	8.4	.104	.012	3.5	2.9	Creosoted in 1931, 8 lbs/cu. f. Removed 1955, line change
3	8	.098	.016	5.4	1.8	.089	.019	6.9	3.1	.096	.012	3.9	1.9	Creosoted in 1936, 8 lbs/cu. f. Removed 1955, line change
Second ½ Inch														
1	4	0.111	0.006	1.8	1.5	.104	.006	1.8	1.5	.105	.006	1.9	1.5	
2	4	.099	.005	1.8	1.0	.096	.015	5.1	3.6	.113	.006	1.6	2.1	
3	4	.090	.008	3.0	0.9	.098	.017	5.8	2.8	.104	.012	3.6	1.5	
Third ½ Inch														
1	4	0.104	0.005	1.5	1.5	.109	.009	2.6	1.4	.108	.002	0.5	1.3	
2	4	.100	.003	1.0	1.4	.104	.014	4.2	3.6	.101	.004	2.1	2.1	
3	4	.106	.008	2.6	1.0	.104	.009	3.6	2.0	.103	.013	2.7	1.3	

semi-micro extraction and by use of color standards for two sets of poles; one from a power company in the Middle Atlantic region and the other from a power company in the Southeast.

Although all but one of the poles from power company A shown in the table were sound, as is indicated by the column headed "Condition when removed", only one of them, pole 6, still contained sufficient creosote to consider it safe for re-installation. It should be noted that pole 1 contained less creosote than laboratory tests indicated as necessary for protection against fungi. These laboratory tests indicate that about 4 pounds of creosote per cubic foot are necessary to protect southern yellow pine against the more common wood-destroying organisms.[4] The reason why pole 1 had not already been attacked can only be surmised, but such conditions as an inadequate amount of moisture present in the pole to support fungus growth, or the presence of creosote that bled out of the pole to the surrounding ground to give a barrier of protection, could have been contributing factors.

The rest of the poles that have more than 4 pounds of creosote per cubic foot remaining in them but not as much as 12 pounds could be re-used with confidence that they would give a worthwhile amount of continued service only if they were re-treated with preservative, or were placed in specially prepared holes treated with some suitable soil-poisoning chemical.

Of the poles from power company B shown in the table, two contained sufficient creosote to make it safe to re-use them as they were. These are poles 7 and 8. Pole 8, although in service 22 years, still contained as much creosote as most freshly treated poles. Several of the poles in this group also had a low creosote content, in the neighborhood of the threshold of 4 pounds per cubic foot, but they still remained sound. Other poles with about the same amount of creosote showed evidence of decay at the groundline (poles 1 and 2).

The poles represented in Table 2 were selected at random, but even in this small sample the difference in the amount of creosote found in poles from power company A (A poles) and power company B (B poles) (see the averages at the bottom of each group) is about the same as it was at the time of treatment; that is, about two pounds per cubic foot. The A poles were originally treated with 8 pounds of creosote per cubic foot, while the B poles were treated with 10 pounds. The creosote content as determined by the use of the color standards, shown in section 2 of the table, averages about half the amount found by semi-micro extraction for the two groups of poles.

By the use of the color standards, B poles show approximately the same average amount of creosote as A poles, but as pointed out above, the semi-micro extraction method showed a difference of about two pounds per cubic foot in the two groups.

The fact that the color standards show only about half the amount of creosote found by semi-micro extraction would not rule against the use of a universal color standard made up from extract from a single pole, such as the 1940 pole used in this case, *provided* all poles showed on the average this same difference. To correct for the difference, it would merely be

[4] Duncan, Catherine G. 1954. Evaluating wood preservatives by soil block tests: 7, progress on the development of a laboratory weathering method. Proc. AWPA. 50: 41.

Table 2.—EXTRACTION OF OLD CREOSOTED SOUTHERN PINE POLES WITH COLD DIMETHYLFORMAMIDE

Pole No.	No. of Extractions	Half Inch Zone: Outer 3 ft. Below Groundline	Second	Third	Half Inch Zone: Outer Groundline	Second	Third	Half Inch Zone: Outer Above Groundline	Second	Third	Date Installed	Condition when removed in 1955
1. Creosote content as Determined by Semi-micro extraction—lbs/cu. ft.												
Poles from Power Company A—Treated with 8 lbs/cu. ft. of Creosote												
1	8	3.7	1.8	1.5	3.1	1.8	2.6	3.3	1.9	0.5	1931	Sound
2	8	2.8	1.8	1.0	10.2	5.1	4.2	3.5	1.6	2.1	1931	Sound
3	8	5.4	3.0	2.6	6.9	5.8	3.6	3.9	3.6	2.7	1936	Sound
4	2	3.8	4.2	4.0	8.5	9.0	9.8	5.3	5.4	3.7	1938	Sound
5	2	8.1	7.6	8.3	6.4	5.6	5.4	4.9	2.9	3.5	1931	Sound
6	2	14.0	8.6	7.9	14.0	15.1	16.0	4.4	6.2	5.1	1938	Sound, Deposit at GL
7	2	10.4	5.5	5.4	11.8	6.8	6.7	8.6	7.9	4.1	1931	Sound, Heavy deposit at GL
8	2	3.8	2.1	1.7	7.1	1.9	1.5	3.9	2.0	1.3	1937	Decay at GL
Average		6.5	4.3	4.0	8.5	6.4	6.2	4.7	3.9	2.9		
Poles from Power Company B—Treated with 10 lbs/cu. ft. of Creosote												
1	2	----	6.0	2.8	6.8	4.8	1.9	4.8	3.2	1.4	1932	Decay at GL
2	2	7.6	4.6	1.7	5.6	6.8	3.3	6.4	5.0	2.0	1941	Decay at GL
3	2	7.8	4.1	3.2	13.0	6.0	1.8	7.6	6.8	4.2	1950	Sound
4	2	6.7	2.5	1.7	10.8	6.3	2.6	5.9	5.0	2.5	1932	Incipient decay at GL
5	2	4.3	10.0	10.9	3.3	6.0	9.1	4.6	4.4	2.8	1931	Sound
6	2	12.9	8.1	12.8	15.4	8.6	13.1	7.5	7.6	14.9	1937	Sound
7	2	20.0	13.6	10.0	25.6	17.7	12.7	11.4	8.8	----	1937	Sound
8	2	7.6	6.8	4.7	9.9	8.4	3.6	7.4	6.4	4.3	1945	Sound
9	2	4.9	2.9	2.8	6.4	3.5	3.0	4.6	6.6	0.5	1940	Sound
10	2	4.9	7.4	3.6	4.0	3.2	2.0	4.5	5.5	1.0	1949	Sound
Average		8.6	6.6	5.4	10.1	7.1	5.3	6.5	5.9	3.4		
2. Creosote Content as Determined by Use of Color Standards—lbs/cu. ft.												
Poles from Power Company A.												
1	8	2.7	1.5	1.5	2.9	1.5	1.4	1.9	1.5	1.3	1931	Sound
2	8	1.9	1.0	1.4	8.4	3.6	3.6	2.9	2.1	2.1	1931	Sound
3	8	1.8	0.9	1.0	3.1	2.8	2.0	1.9	1.5	1.3	1936	Sound
4	2	1.8	1.0	1.0	4.0	2.3	2.5	2.0	1.5	1.5	1938	Sound
5	2	7.5	4.5	5.5	4.3	3.5	2.5	3.8	2.0	1.5	1931	Sound
6	2	4.8	2.5	1.5	4.0	3.3	3.0	2.5	2.5	1.5	1938	Sound, Deposit at GL
7	2	5.8	2.5	2.5	8.0	3.5	4.0	5.0	5.3	2.5	1931	Sound, Heavy deposit at GL
8	2	1.8	1.3	1.5	6.5	3.8	4.5	3.5	3.0	3.5	1937	Decay at GL
Average		3.5	1.9	2.0	5.1	3.0	2.9	3.0	2.6	2.0		
Poles from Power Company B.												
1	2	----	3.3	2.5	5.0	3.5	2.0	2.5	3.5	1.5	1932	Decay at GL
2	2	1.8	1.5	1.5	4.0	3.3	3.5	3.8	2.8	1.5	1941	Decay at GL
3	2	2.8	1.3	1.0	1.8	2.0	2.5	2.8	4.0	4.0	1950	Sound
4	2	3.0	1.8	1.5	7.8	4.5	3.5	3.5	3.0	2.5	1932	Incipient decay at GL
5	2	3.0	5.0	3.0	3.0	2.8	2.5	2.3	1.8	1.5	1931	Sound
6	2	4.5	2.3	1.5	4.5	2.5	2.0	2.8	1.8	1.5	1937	Sound
7	2	7.8	3.8	3.0	9.5	5.3	5.0	4.0	2.3	2.0	1937	Sound
8	2	3.3	2.3	2.5	4.3	3.3	2.0	3.0	2.5	2.5	1945	Sound
9	2	1.3	1.0	1.5	3.8	1.5	1.5	2.0	3.5	1.5	1940	Sound
10	2	2.8	3.5	1.5	3.8	1.8	2.3	4.3	2.5	2.5	1949	Sound
Average		3.0	2.6	2.0	5.3	3.1	2.7	3.1	2.8	2.1		

necessary to use double the strength of colorimetric stock solution. However, the fact that the poles from one power company show an average creosote content about 2 pounds per cubic foot higher than those from the other power company by the semi-micro extraction method, while the results are the same for the color method, shows that this method of correcting the colorimetric test cannot be used. The results indicate that, in order to obtain satisfactory correlation between the semi-micro and colorimetric methods, one would have to be more specific in selecting material from which to obtain extracts than to arbitrarily select a pole for a universal standard.

Fig. 3 contains plots of the averages for the two groups of poles shown in Table 2. The curves on the left show the distribution of creosote in the outer 1½ inches of these poles as determined by the semi-micro extraction method, while those on the right show the results obtained by use of the color standards. The curves show the lowest concentration of creosote to be in the above groundline section, the heaviest concentration at the groundline, and an intermediate amount in the section below the groundline. The pattern of the curves for creosote distribution obtained by the colorimetric method is similar to that obtained by the semi-micro extraction method except in the case of the below-groundline zone for the B poles.

Fig. 4 represents the average data for creosote content by semi-micro extraction taken from Table 2, plotted against the creosote content determined by color standards. Both sets of data show a linear relation between the amount of creosote found by semi-micro extraction and the amount indicated by the color tests. The line for the data for the B poles is steeper than that for A poles, which indicates that, with a given amount of creosote in the solution, the solutions from B poles tend to be lighter colored than those from A poles. The arrangement of the points around this straight line indicates the following:

1. The color of the extracts taken from each half-inch section of a boring will be the same for a given amount of creosote. (The data for the outer half inch at the groundline may represent an exception.)

2. Below-groundline sections tend to show slightly less color with a given concentration of creosote than do the groundline sections. Sections above the groundline tend to show the darkest color for a given amount of creosote.

Conclusions

The data obtained indicate that it is possible to determine the amount of creosote in old poles by a colorimetric method. It demonstrates also that *no single standard* can be used for poles treated with differing types of creosote installed in different localities at different periods of time.

Further study to evaluate the effect of variables such as age of the poles, type of creosote used in treatment, and so forth, on the color of extracts from the poles should result in refinements of the technique so that it can be applied to testing of old poles with an accuracy equal to that obtainable with the semi-micro extraction method described.

The data show that, when a *given set* of standards is used, the test borings may be taken at any point on the pole, below the groundline, at groundline, or above groundline, or from the outer half inch, the second half inch, or the third half inch, with an expectation of checking within about 1 pound per cubic foot of the value that would be obtained by extracting borings from the pole by the semi-micro extraction method.

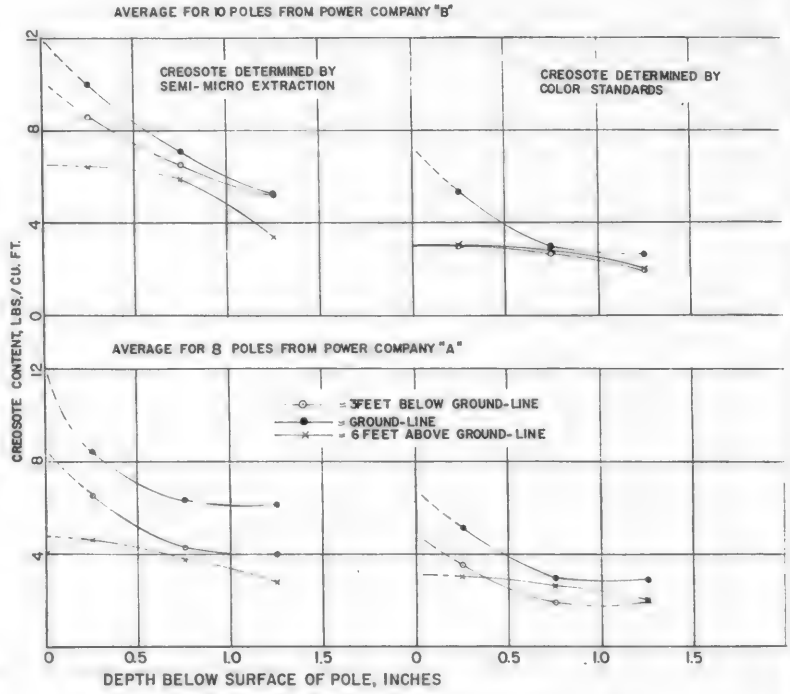

AVERAGE FOR 10 POLES FROM POWER COMPANY "B"
CREOSOTE DETERMINED BY SEMI-MICRO EXTRACTION
CREOSOTE DETERMINED BY COLOR STANDARDS
AVERAGE FOR 8 POLES FROM POWER COMPANY "A"
= 3 FEET BELOW GROUND-LINE
= GROUND-LINE
= 6 FEET ABOVE GROUND-LINE
CREOSOTE CONTENT, LBS./CU. FT.
DEPTH BELOW SURFACE OF POLE, INCHES

Fig. 3.—Creosote distribution in 18 old southern pine poles.

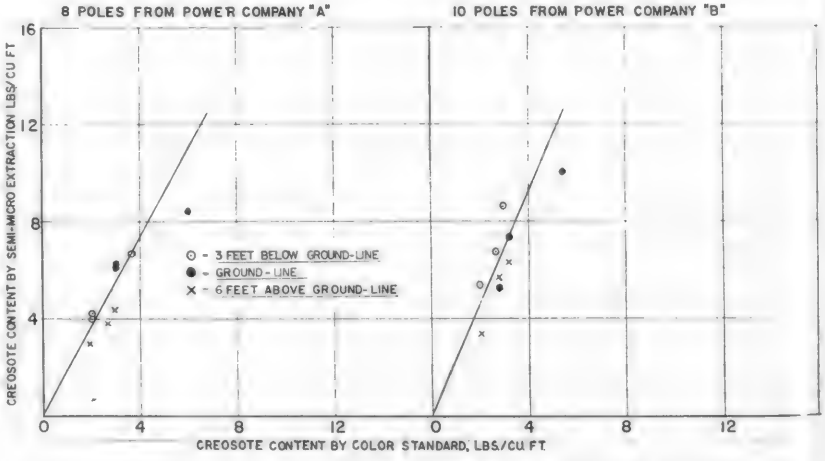
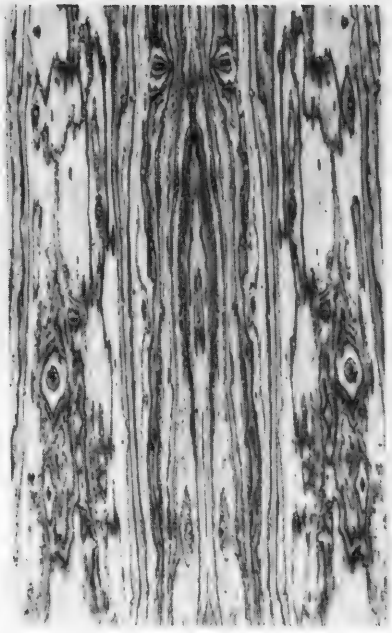

8 POLES FROM POWER COMPANY "A"
10 POLES FROM POWER COMPANY "B"
CREOSOTE CONTENT BY SEMI-MICRO EXTRACTION LBS/CU FT
○ - 3 FEET BELOW GROUND-LINE
● - GROUND-LINE
× - 6 FEET ABOVE GROUND-LINE
CREOSOTE CONTENT BY COLOR STANDARD, LBS./CU FT

Fig. 4.—Creosote content of old southern pine poles as determined by micro-extraction versus color standards.

Brazilian Rosewood



Canalete

Purpleheart

PROPERTIES AND USES OF High-Density Imported Woods[1]

J. L. Stearns
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Philadelphia, Pa.

Although nothing could replace hickory for axe handles, for instance, some foreign woods do fill specific needs of our industry. All major high-density woods imported from around the world are described here.

THE SEARCH FOR THE BEST WOOD for a given purpose has commanded the attention of men since the very beginning of recorded history. Solomon, for instance, was not content with the prosaic odor of Lebanon cedar, so, according to historians, he dispatched 80,000 axemen to the shores of North Africa with instructions to find a more beautiful, more aromatic wood for the walls of his fabulous temple. They discovered the rare and beautiful Thuya, or thyine wood (14)[2] as it was called later in the Bible, a wood so beautiful, so fragrant, that Solomon was overjoyed. He apparently ordered great quantities of the original stand to be cut, because by the time Cicero heard about the wood it was really scarce, and commanded a high price. According to one account (18), Cicero's wife found among her husband's personal papers a receipt for "one Thyine burl table—300,000 denarii" ($50,000.)

[1] Presented at the Fall Meeting of the Northeast Section, FPRS, held Oct. 31–Nov. 1, 1957, in New York City.

The Author: Joseph Stearns holds a BS degree in forestry from Penn. State University. He has been engaged in lumber manufacture and forest nursery operation, followed by 17 years in wood research.

Traditional Wood Uses

The search for the best wood has ostensibly ended in the case of many items. Stradivarius in 1690 determined that violins should have spruce on the belly, maple on the back, ribs and neck, and that the pegs, finger-board, and tailpiece should be ebony. No one has thought of any better combination since.

Abner Doubleday and his baseball followers decreed that American white ash was the best bat wood, and in every big league game played to date ash has driven the ball.

American hickory, first used by our colonists for axe handles, points out another unbeatable wood application. Even today there are many countries of the world that can boast of a far greater selection of hardwoods than the U. S., yet while they search for a better wood from their own forests, their axemen use imported U. S. hickory handles.

There are many other examples of traditional wood uses: for instance, lignum vitae stern tube bearings, teak ship decks, walnut gunstocks, hard maple shoe lasts, boxwood engraving blocks, and so forth, the point being that industry will use the wood proved to be the best for the purpose when top-quality products are required, regardless of whether it is an imported or domestic species.

[2] Numbers in parentheses refer to the Literature Cited.

Why Foreign Woods are Used

In the U. S. we use a great many foreign woods. Some are imported because 1) they possess certain characteristics not available in any domestic species, 2) they may be less expensive, 3) they satisfy the demands of luxury merchandise buyers, or 4) they provide certain decorative effects not possible or practical to obtain with any indigenous wood.

The most important properties and uses of the principal high-density imported woods used by American industry will be described here. It is believed that the most logical way to start is by dividing the world into six geographical regions as follows:

1. North America—U. S., Canada, Alaska
2. Tropical America—Mexico, W. Indies, C. America, S. America
3. Africa—Entire Continent
4. Europe—East to 60° longitude
5. Asia—60° to 150° longitude
6. Oceania—Australia, N. Zealand, Hawaii

1. North America. . . . Since there are no commercial woods north of the Canadian line that are not also produced in the U. S., we shall disregard this region.

2. Tropical America. . . . Out of the many thousands of species found in this vast region, only about 12 are being imported in any substantial volume, and about 25 others in small quantities.

Mahogany has always been the outstanding wood from Tropical America. Its use in our furniture industry rises and diminishes with economic conditions, but there never has been a time when it has not occupied a prominent position among fine cabinet woods.

Adhering strictly to the title of this paper makes the selection of qualified species difficult. *Swietenia mahoganii* logs from Cuba and even on the Florida Keys have been found with specific gravities recorded above 0.80, which would unquestionably place them in the "high-density" class. We have not imported any Cuban mahogany, however, since the Cuban government placed an embargo on it years ago. The other countries and islands of the West Indies have insufficient mahogany for their own needs and rarely export any. The Swietenia species from Central and South America are not as dense as the Cuban wood. Average specific gravities range approximately 0.50 to 0.60 (15).

The following list of important Tropical American woods currently being imported into the U. S. shows the first 12 previously mentioned as being in the large-volume class and the others, not necessarily in order of their importance volume-wise, following.

The high-density species (those averaging over 44 pounds per cubic foot air dry) are in heavy type.

Large Volume

1. **Mahogany**—*Swietenia macrophylla* King
2. **Parana pine**—*Araucaria angustifolia* (Bert.) O. Ktze
3. **Cativo**—*Prioria copaifera* Gris.
4. **Greenheart**—*Ocotea rodiaei* (R. Schomb) Mez.
5. **Banak**—*Virola merendonis*—Pitt. & V. sur.
6. **Balsa**—*Ochroma lagopus* SN.
7. **Caribbean pine**—*Pinus caribaea* Morel
8. **Spanish cedar**—*Cedrela* mostly *mexicana* Roem.
9. **Lignumvitae**—*Guaiacum officinale* L.
10. **Brazilian Rosewood**—*Dalbergia nigra* Fr. Allem.
11. **Primavera**—*Cybistax donnell-smithii* (Rose) Seib.
12. **Cocobola**—*Dalbergia retusa* Hemsl.

Small Volume

13. **Goncalo Alves**—*Astronium fraxinifolium* Schott & A. *graveolens* Jacq.
14. **Quebracho**—*Schinopsis lorentzii* and *S. balansae*—Engl.
15. **White Peroba**—*Paratecoma peroba* (Rec) Kuhl.
16. **Canalete**—*Cordia gerascanthus* L.
17. **Venezuelan Boxwood**—*Gossypiospermum praecox* (Gris) P. Wils.
18. **Albarco**—*Cariniana pyriformis* Miers.
19. **Brazilian Kingwood**—*Dalbergia cearensis* Ducke
20. **Brazilian Tulip**—*Dalbergia frutescens* var. *tomentosa* Stand.
21. **Honduras Rosewood**—*Dalbergia stevensonii* Stand.
22. **Angelique**—*Dicorynia guianensis* Amsh.
23. **Guanacaste**—*Enterolobium cyclocarpum* (Jacq.) Gris.
24. **Pernambuco**—*Guilandina echinata* (Lam) Spreng
25. **Purpleheart**—*Peltogyne paniculata* Benth.
26. **Andiroba**—*Carapa guianensis* Bubl.
27. **French Satinee**—*Brosimum paraense* Huber
28. **Snakewood**—*Piratinera guianensis* Aubl.
29. **Lemonwood**—*Calycophyllum candidissimum* (Vahl) DC.
30. **Orangewood**—*Citrus* spp.
31. **Brazilian Satinwood**—*Euxylophora paraensis* Huber
32. **Beefwood**—*Manilkara bidentate* (A. DC.) A. Chev.
33. **Santa Maria**—*Colophyllum brasiliense* Camb.
34. **Guayacan** (vera) & (Bethabara)—*Bulnesia arborea* Jacq. and Tabebuia spp.
35. **Louro**—*Ocotea rubra* Mez.
36. **Itauba**—*Mezilaurus itauba* (Meissn) Taub.
37. **Imbuya**—*Phoebe porosa* (Nees & Mart.) Mez.

Attempts have been made over a period of many years to introduce other species, but without much success. The reason is primarily that little or no technical, or even practical, information is available. Most manufacturers are very hesitant about buying an unknown wood. When approached on this subject they usually want to know:

1. "With what well-known wood does it compare most closely?"
2. "If I go to the expense of promoting it, what assurance do I have that large, continuous supplies of the same species, grade, quality, and texture will be available?"
3. "How do I know it will give satisfactory service, for instance, in the matter of dimensional stability, resistance to decay, splitting, darkening of color, and so forth?"

Confronted with the above blockades to success, many a tropical wood has fallen by the wayside.

Most of the naturally colorful woods gradually turn dark—almost black—over the years. Purpleheart, for instance, goes through a radical color change. It is a pale brownish, non descript color when freshly planed but changes within a few days to a beautiful bright purple. At this time it it admired by a great many unknowing wood lovers who have not had the disappointment of seeing this lovely purple gradually turn to a deep plum color, then later almost black.

Purpleheart is not the only offender in color changing. Nearly all the colorful woods are guilty; to name a few others, the bright red "vermilian wood" or Padouk turns so dark that it too looks black in the average room light; the bright, golden color of freshly planed osage orange turns a dirty brown in just a short time. Antique art objects made of teak are often practically black, even though no pigment is contained in the original lacquer, thus explaining the fact that many people today think that teak is naturally black, even in the fresh wood.

The above all pertains to wood objects kept indoors and finished with natural, transparent varnishes, lacquers, and so forth, and not to bare wood surfaces exposed continuously to outside weathering. In the latter case, all woods bleach to a bone gray hue in time.

The high-density woods in the list above are described briefly as follows:

Greenheart

A greenish-colored, heavy, dense, straight-grained hardwood having an average weight of 80 pounds per cubic foot in "shipping dry condition." Nearly all the production comes from British Guiana, the greatest volume being in the form of round piling and

Reportedly the largest sawmill in the Orient, this Insular double band mill cuts 180,000 board feet of Philippine hardwoods daily.

heavy squared timbers and planks used in lock gate, wharf, and pier construction. The wood is world-famous for teredo resistance. It is likewise extremely durable in contact with wood-destroying fungi. (23)

Lignum-Vitae

An internationally famous, hard, oily wood that is erroneously believed to be the world's heaviest, though there are many others in the same weight class and a few that exceed it. The natural color of the heartwood is a dark olive green; sapwood is pale yellow, and the grain is finely interlocked. Splitting even very short stovewood lengths of lignum-vitae logs is impossible with an axe and sledge hammer. It will split across short sections when severely stressed, however, as the following story indicates.

During the Civil War, the Confederate cruiser "Georgia" had—"engines fitted with lignum-vitae cogs, and frequently these wooden cogs would break. When they did, it was worse than if a shrapnel shell had burst in the engine room, as they flew in every direction, endangering the lives of everyone within reach." (5)

Today, the use of lignum-vitae is quite restricted. Some pulley sheaves are still produced, but the principal item is stern tube bearings—especially for submarines, where an absence of noise is vitally important. It is no longer used to any extent in large surface vessels, because it has been replaced by micarta, cutlass rubber, and other man-made products. Mallet heads, venetian blind pulleys, spuds, dead eyes, motor mounts, specialized industrial machinery for rollers, bearings and polishing sticks, are among other known uses.

Brazilian Rosewood

This is a dark reddish wood of many figure and color variations, mostly black bands and pencil stripes over rose or purple undertones, very occasionally with lighter pinkish or yellow straw colors in the background. The surface is rather oily, though not to the extent of teak, and for this reason gluing requires special technique.

It is quite heavy, ranging mostly in the order of 52 to 56 pounds per cubic foot, and although strong, its present uses are such that mechanical strength is unimportant.

Years ago it was the favorite wood of the piano industry (18), and during the Victorian period, much fine furniture was manufactured from rosewood. Today it is still available mainly in the form of logs for veneers, but in a much more limited volume than in the 19th century. The Netherlands Plaza Hotel in Cincinnati contains some excellent veneered panels, and there are many fine offices, banks, and commercial interiors paneled in this dark, handsome, Brazilian wood.

The logs are best cut into veneer by the "half round" lathe. This develops the full beauty of its pigment lines better than either plain or quarter slicing.

The cutlery industry uses Brazilian rosewood to supplement cocobolo for knife handles, and our finest grade billiard tables are generally fitted with broad rosewood rims around the top, framing the green felted slate.

Cocobolo

Though closely related to the preceding rosewood, cocobolo logs are lacking in shape, size, and beauty to be useful for veneers. It has a wider, dark, pigmented streak through the wood. Freshly cut, unseasoned cocobolo is orange with purplish lines that turn dark red with black lines quickly after seasoning. It is used for very little else than cutlery handles.

Very hard and easily polished, cocobolo is reputedly the best natural wood for this purpose because of its ability to withstand repeated exposures to boiling hot, soapy water without checking or bleaching. The handles are handsome and smooth, even without any finish applied to the surface.

Goncalo Alves

Goncalo alves is a hard, reddish-brown timber with pronounced black streaks, which appear broken, like a woven pattern on quartered surfaces. This is due to the characteristic spiral grain growth. There is not enough of the wood to interest any importers in conducting a specific advertising or promotional campaign but, oddly enough, a number of them carry a small inventory of lumber and veneer, which is sold occasionally for architectural woodwork, where something out of the ordinary is desired.

Quebracho

This name, translated into English, means "axe breaker", which is sufficient to describe its extreme hardness (15). It is a wood used in commerce mainly for its tannin extract, although the leather industry uses many other tannins from bark, nuts, and woods to supplement quebracho.

The wood itself is rarely imported into the U. S., since the extraction of the tannin is done in Argentina and Paraguay, where there are about 25 factories. With 20 to 30 per cent of tannin in the heartwood, it is no wonder that quebracho is one of the world's most decay-resistant woods.

Timber exporters in Paraguay attempted to introduce quebracho fence posts into the U. S. market about six years ago, but the venture failed because of the high transportation costs and almost unbelievably heavy weight of the posts. The first futile attempts to drive staples or nails into the wood promptly ended this brief chapter in its history.

Quebracho weighs between 70 and 80 pounds per cubic foot. There are two species used commercially for tannin. When freshly sawn, the wood is a pale flesh color but soon turns dark red because of oxidation. It has an interlocked grain, and the surface is very smooth when sanded—almost like polished marble. It is now being imported into the U. S. in limited quantities for use in die blocks.

Table 1.—STRENGTH PROPERTIES OF THE LEADING FOREIGN WOODS IMPORTED INTO THE UNITED STATES

SPECIES	Moisture Content	SP. GRAV. Oven Dry	SP. GRAV. Green	STATIC BENDING Fiber Stress at Prop.Lim.	STATIC BENDING Mod. of Rupture	STATIC BENDING Mod. of Elasticity	COMP. PARALLEL TO GRAIN Fiber Stress at Prop. Lim.	COMP. PARALLEL TO GRAIN Maximum Crushing Strength	HARDNESS End	HARDNESS Side	SHEAR Parallel to Grain Max.Shear
TROPICAL AMERICA											
Mahogany (7)	12	.50	.45	8,810	11,140	1,430,000		6,430	880	760	1,050
Parana Pine (24)	12.8	.50			12,400	1,650,000		6,700	1100	790	1,750
Cativo (3)	81.2	.44	.40	3,240	5,920	940,000	1,610	2,460	460	440	860
GREENHEART (12)	14.8	1.06	.88	16,200	25,500	3,700.000	10,000	12,920	2140	2630	1,830
Banak (3)	11.4	.50	.42	6,900	10,950	2,040,000	3,330	5,140	560	510	980
Balsa (4)	5.0	.144			2,160	456,000		1,045			
Caribbean Pine (3)	13.1	.78	.68	9,850	16,690	2,240,000	4,960	8,540	1180	1240	2,090
Spanish Cedar (7)	12	.38	.34	5,940	7,860	1,010,000		4,450	580	500	
LIGNUM VITAE (24)	12	1.09						11,400	3600	4500	
BRAZIL. ROSEWOOD (24)	5.7	.72								2130	
Prima Vera (7)	12	.44	.40	6,220	9,940	1,200,000		6,460	1060	730	
COCOBOLO (24)	5.7	1.06								3860	
GONCALO ALVES (3)	46.2	.95	.84	8,510	12,140	1,940,000	4,620	6,580	1640	1910	1,760
QUEBRACHO											
WHITE PEROBA (24)	15	.73			16,900			7,840		1035	
CANALETE											
VENEZ. BOXWOOD											
Albarco											
BRAZIL. KINGWOOD											
BRAZIL. TULIP (24)	5.7	.94								3460	
HOND. ROSEWOOD											
ANGELIQUE (22)	78.7	.69	.60	7,650	11,410	1,840,000	4,810	5,590	1100	1100	1,340
Guanacaste											
PERNAMBUCO											
PURPLEHEART (12)	13.9	1.05	.92	16,300	25,100	3,640,000	9,970	13,270	3350	3640	2,070
Andiroba (3)	65.0	.60	.54	6,640	10,300	1,690,000	4,040	4,780	940	880	1,220
FRENCH SATINE											
SNAKEWOOD											
LEMONWOOD (3)	14.2	.78	.67	12,430	22,300	2,270,000	5,180	9,670	2140	1940	2,120
CHANGEWOOD											
BRAZ. SATINWOOD											
BEEFWOOD (3)	47.6	1.03	.85	11,120	17,310	2,700,000	7,030	8,690	2160	2230	1,900
Santa Maria (3)	13.1	.60	.52	9,000	14,640	1,830,000	4,860	6,910	1410	1150	2,080
GUAYACAN * (3)	35.4	1.00	.85	11,060	18,480	2,580,000	6,600	7,680	2270	2530	2,140
Louro ** (3)	52.2	.71	.62	10,250	12,840	2,040,000	5,130	6,000	1060	1130	1,360
Itauba (3)	14.2	.77	.68	9,910	15,200	2,040,000	5,270	8,590	1210	1370	1,560
Imbuya											

* Tabebuia guayacan ** Ocotea sp.

				A.D.							
AFRICA											
African Mahogany (7)	12	.47	.43		7,890	10,700	1,480,000	5,680	1080	790	1,340
Limba (Korina) (19)	10.3			.44	6,230	7,968	1,272,000	4,570	5,740		1,340
Okoume (19)	12			.37	5,760	7,350	1,145,000		10,350	1560	980
Sapele (19)	12		.54	.57		9,500	1,450,000		8,320	1670	1380
Utile (19)	12		.55	.57		14,200	1,670,000		8,440	1790	1260 2,160
Makore (19)	12			.63		12,900	1,420,000		6,220	1560	1380
Ayous (19)	12		.31	.33		7,500	850,000		3,940	690	430 990
Zebrawood (24)	5.4			.74							1745
Movingui (19)	12			.60		14,900	1,760,000		8,000	1650	1230 1,860
Agba (19)	12			.44		11,290	1,210,000		5,680	990	700 1,375
Iroko (19)	12		.54	.56		11,900	1,360,000		6,950	1340	1100 1,710
Afrormosia (19)	12			.61		19,390	1,810,000		10,350		1560
AFRICAN BLACKWOOD											
BUBINGA (24)	4.6	.72									2235
Padouk (19)	12			.77	12,380	14,720	2,290,000		8,200		1540
Bosse (19)	12		.47	.49		14,100	1,460,000		7,440	1220	900 1,970
Tigerwood (19)	12		.45	.49		11,300	1,430,000		6,730	1130	940 1,280
Avodire (19)	12			.51		12,700	1,480,000		7,180	1440	1080 2,040
Mansonia (19)	12		.53	.57		16,800	1,690,000		8,190	1680	1290 1,980
EBONY (19)	12			.90		26,000	2,730,000		12,860	3430	3220 2,480
Emeri (19)	12		.42	.41		12,000	1,400,000		6,320	1130	750 1,600
ASIA											
Phil. Mahogany * (7)	12	.57		.54	8,590	12,270	1,690,000		6,830	780	840 1,570
Teak (9)	52		.60		7,090	11,440	1,670,000	4,075	5,870	915	1038 1,107
APITONG (6)	12		.58	.63	7,700	12,300	1,940,000	5,300	6,200	910	880 1,330
White Seraya (9)	73		.42		4,620	8,030	1,430,000	2,710	4,410	660	605 880
Ramin											
Japanese Oak (2)	12			.59	8,760	14,190	1,670,000	5,100	8,340	1830	1220 1,180
Japanese Birch (2)	12			.57	8,420	13,530	1,630,000	4,960	7,970	1600	1090 1,350
GUINEA WOOD											
MALDAO (25)	5.6	.73									1300
Sen (2)	12			.45	6,880	10,560	1,430,000	4,310	6,330	800	610 660
BOXWOOD (25)	4.6	.93									3220
E. INDIAN LAUREL (25)	5.8	.90									3160
Palosapis (11)	15	.54			5,380	10,180	1,550,000	3,780		800	780 1,220
Bagtican ** (16)	16	.57		.65	6,883	11,163	1,735,000	4,750		774	818 1,255
MACASSAR EBONY (24)	6.1	1.15									5030
CEYLON EBONY											
Japanese Beech (2)	12			.54	8,060	12,830	1,580,000	4,810	7,590	1380	960 1,260
Camphor Wood											
E. INDIAN ROSEWOOD (24)	12	.79				16,600	1,770,000		9,100	2960	3170 2,070
Narra ** (16)	58	.52	.82		6,983	11,035	1,437,000	4,579		1157	1115 1,279
Andaman Padouk (24)	12	.64				14,500	1,740,000		8,590	1520	1540 1,520
Tamc (Jap. Ash) (2)	12			.51	7,710	12,140	1,540,000	4,660	7,210	1180	840 1,240
Japanese Cherry (2)	12			.55	8,180	13,050	1,600,000	4,860	7,720	1450	1000 1,300
E. IND. SATINWOOD (24)	5.4	.79									2315
Meranti (9)	63	.53	.46		4,640	7,710	1,650,000	2,960	4,200	660	575 930

* Tangile (Shorea polysperma Merr.)
** Values translated from metric system

OCEANIA											
Oriental wood (24)	12					13,900	1,780,000		9,020	1720	1400 2,140
JARRAH											
KOA (25)	6.2	.59									1205
IRONBARK (26) *			.91			17,750	2,655,000		9,415		1,896
Yuba (25)	6.0	.65									1035
Australian Maple (25)(26)*	6.1	.69		.69		14,493	2,085,000				1385
Aust. Blackwood											
Blackbean (26) *				.84		12,616	1,689,000		6,087		2,477

* Values obtained by Swain translated from metric system

White Peroba

Anyone who has handled any volume of this pale-yellow hardwood will never forget the sparkling, crystal-like tyloses in its pores. They appear as minute diamonds in reflected light. While the wood itself is heavy, hard, and more durable than our native oak, it is viewed with suspicion by U. S. boat builders because it cannot be steam-bent satisfactorily. Actually it will yield to mild bends, but in the rather severe standard U. S. Navy test wherein an 8/4 by 3 inch section must be bent around a 16-inch radius, it fails every time in compression. In spite of this, it was used with good success in World War II for frames in some of the smaller naval craft on the Pacific Coast.

White peroba should not be confused with Peroba rosa, a much weaker but more colorful, pink cabinet wood from South America. The writer has seen 16-by-24-inch timbers of White peroba arriving at Terminal Island, Cal., from Brazil that were 40 feet long, free of boxed hearts, and without any visible knots or other defects. This would be impossible to obtain in oak or any other temperate-zone hardwood. Record and Hess (15) quote a New York "cabinet-maker" as having stated: "Peroba is a yellowish, moderately hard wood obtained in logs sometimes 30 inches through. It takes stain fairly well, is of about the color of greenheart and has a texture suggesting Santo Domingo satinwood." With all due respect to the author of this statement, it should be pointed out here that cabinet makers are not usually buyers or importers of logs, and it must have been another wood that the cabinet-maker in question was describing, since peroba is definitely not the color of greenheart nor the texture of satinwood; moreover, a 30-inch peroba log would be below average in size. Mature timber reaches 60 inches or more in diameter, and "export quality logs" frequently 72 inches are readily available according to Pacific Coast importers who have attempted to popularize the wood, so far with little success, it must be admitted. As the supply of high grade domestic oak becomes more scarce, however, woods like white peroba will no doubt become more and more important to U. S. industry.

Canalete

This odd-looking, attractive wood was first noticed by the writer just before World War II when the Venezuelan Embassy was built in Washington. A local millwork concern received a shipment of canalete along with some goncalo alves lumber direct from Venezuela to be used for the interior paneling and trim in the new embassy. The purplish undertones and dark streaks of the canalete have been admired by many people who have visited this building over the past several years.

Canalete weighs 50 to 60 pounds per cubic foot and has a straight grain except in very occasional logs that may show a roe figure. Uses in the U. S. are limited to small furniture items, brush backs, and occasional architectural paneling and woodwork installations.

Venezuelan Boxwood

When the original wood of English and Turkish boxwood became scarce and high in price, a worldwide search was started to find substitutes. A surprisingly similar wood was discovered in Venezuela. No one but a wood anatomist could tell it from the original English and Turkish box. It has all the desirable properties and grows to a slightly larger size. This enabled the manufacturers of precision scales, scientific apparatus, and engraving blocks to obtain higher quality rough lumber, and today, it is the only real source of boxwood.

No wood could possibly exceed boxwood for precision lathe turnings. It is a joy to any wood turner. The color and fine grain suggest ivory, yet in spite of its hardness, boxwood is easy to cut. It is world-famous for dimensional stability, once dried thoroughly.

Brazilian Kingwood

Although rare and beautiful, kingwood, like others in the rosewood genus, has had its day. The demand has all but disappeared in this country.

Once the favorite of King Louis XIV of France (18), it was probably named "kingwood" for this reason, although violetwood is a name heard for it just as often. The logs, like tulip, are very small and exceedingly hard, so that they also must be sawn rather than sliced to produce veneer. The kerf waste in sawing exceeds the volume of wood remaining as veneer, thus adding to the cost.

When freshly sawn, the color is deep violet or purple, but fades to a dull reddish-brown with pigmented streaks, resembling Brazilian rosewood. Its weight of 75 pounds per cubic foot (15) plus the scarcity and small size all contribute to the high cost, and limit its utility to marquetry and inlays for fine furniture.

Brazilian Tulip

It is unfortunate that the delightfully fragrant odor so noticeable in sawing this wood does not persist after the machining has been completed. If it did, we might even find it used for lining a lady's clothes closet.

The wood is actually one of the Dalbergias, or rosewood species, although its color, which consists of pink stripes over a straw-colored background, in no way resembles the other much darker rosewoods.

In weight and hardness, tulip is in the class of black ebony, running between 56 and 69 pounds per cubic foot. Its hardness makes veneer slicing extremely difficult; consequently, veneers are sawn.

The logs are so small that veneer flitches are rarely over 10 inches wide. This wood, along with black ebony and kingwood, are among the so-called "fence post size" logs imported into the U. S. (20). Tulip is a favorite wood for veneered borders and inlays, but is rarely used for entire furniture surfaces.

Honduras Rosewood

This is the "xylophone wood", so called because it is the favorite wood for the bars of marimbas and xylophones.

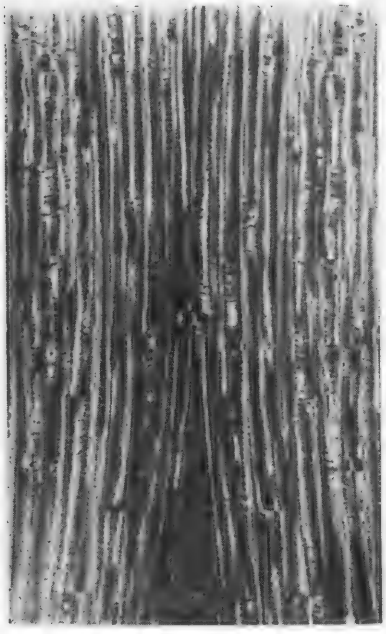
Honduras rosewood has a natural resonance possessed by very few other species, although tests by Dr. Clay Huff and the writer on a number of other species indicated that fustic, *Chlorophora tinctoria*, and pernambuco, *Guilandina echinata*, developed tones almost as distinct and musical.

The wood weighs from 58 to 68 pounds per cubic foot air dry (15) and is a brownish color with faint lavender-toned streaks. Its toughness and elasticity are believed to exceed other resonant hardwoods, enabling it to withstand the repeated impact of the mallet.

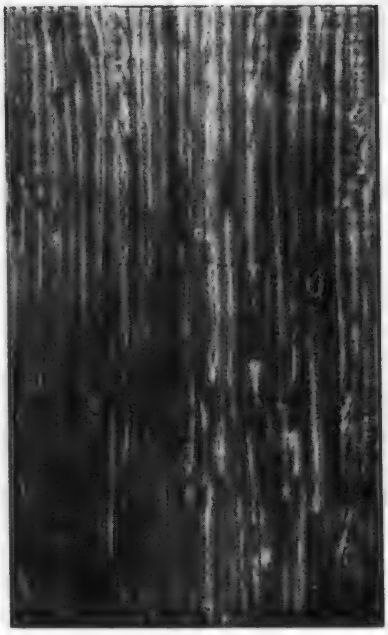
Angelique

This is the British Guiana hardwood that showed up so well as a potential shipbuilding wood in the Yale tests (3). Until recently, it was practically unknown on the U. S. market, although one large Dutch lumber mill in Surinam has been using it for flooring manufacture for several years. This flooring is exported mainly to Europe, where it is regarded very highly.

The writer's experience with the wood has been limited to cutting only a few 12/4 planks, all of which were so filled with silica that saw blades would become dulled beyond usefulness in a matter of a minute or two. The material processed at Yale, however, according to Dr. Wangaard, gave them no trouble from this standpoint. This seems to indicate that some logs may contain silica and others little or none.



Satinwood



Bubinga

Indian Laurel

The wood weight is from 45 to 56 pounds per cubic foot (10). It is basically a dark, tobacco-brown color with either a purplish or reddish cast and fine dark streaks on the quartered surface.

Two U. S. importing firms are now attempting to introduce angelique to American industry, but progress is slow because of the reasons outlined at the beginning of this paper.

Pernambuco

This is the bright-orange, fine-grained, hard and heavy wood used for high-priced violin bows. It is not used commercially for anything else, consequently the volume of logs imported is practically negligible.

The logs are small, high in price, and very defective as a rule. This means that there is a tremendous waste in obtaining a few perfect bow blanks from a log.

Purpleheart

Purpleheart, or amaranth, is an attractive wood while it is purple, but it never has and probably never will become important commercially because its color is its only asset, and that is not stable. If we were to dye American hickory purple, for all practical purposes we would have amaranth at about ¼ the cost.

The wood is used to some extent in the butt ends of billiard cues, because of the heavy weight and contrasting color.

Snakewood

This intriguing wood represents the ultimate among all commercial woods in hardness and density. Some specimens have shown a specific gravity of 1.42 on an air-dry, volume basis.

The name "snakewood" comes from the resemblance of the mottled black pigment over the reddish brown background, to the markings on certain snake skins.

The principal use of the wood was formerly for gentlemen's canes or "walking sticks", but with the gradual disappearance of that market it has had very little left to justify it being classed as a commercial wood. A small number of logs are cut and sold each year to amateur woodworkers. It is very expensive. Good sound pieces are worth $4.00 to $6.00 per board foot, depending on the attractiveness of the figure.

French Satine

Here is a wood so lovely, so beautiful and so nice to work that the finest mahogany seems coarse and unattractive by comparison. Unfortunately, the trees are small and good logs rare, so that the price of French satiné is several times that of mahogany, to which it bears some resemblance. It is redder in color, takes a much nicer finish, planes and sands more smoothly, and is very stable.

The only reason this wood is not one of the world's most popular furniture woods is because of its scarcity. It weighs 56 pounds per cubic foot, but for a wood of such high density, it is not difficult to season or machine. The few logs brought into the U. S. are used for expensive custom furniture, jewel boxes, carvings, and fine brush backs.

Lemonwood

The toughness and elasticity of this fine-grained, pale-yellow wood account for its use in archery bows. Before the development of fiberglass and laminated bows, lemonwood was used in quite a substantial tonnage, but it is gradually disappearing now.

Orangewood

Because it remains so smooth and firm, and its fine, uniform grain does not injure the nails, orangewood has been a favorite material for manicurist's sticks. The logs from which the commercial wood supply is obtained are exported from Central America.

Brazilian Satinwood

Brazilian satinwood is a beautiful and very satisfactory wood. It is not as hard as Ceylon satinwood, to which it is not related, although it is a more desirable wood in many ways. Its color is a more brilliant yellow, more lustrous, and the wood is easier to work. It does not have the reputation of Ceylon satinwood, probably because it has not been known as long.

Judging from some of the large 8/4-inch planks of Brazilian satinwood received from New York importers, the tree must attain a large diameter. Heights of 130 feet are reported, along with references to the "large size of the boles" (15), hence we could count on a more dependable supply of satinwood from Brazil than from anywhere else in the world.

Reports that Brazilian satinwood lacks attractive figure are true if it is compared with something like bee-

Macassar Ebony

Koa

swing figure and narrow ribbon stripe, but its luster, especially upon lacquering, is unexcelled.

Beefwood

No doubt the name beefwood was suggested by the close color resemblance to beefsteak, although the wood is also frequently called "bulletwood", an allusion to its hardness.

There are many species occurring in various parts of tropical America. In fact, it is so frequently encountered that there have been many attempts to promote it over the years. Record and Hess (15) mention its use for factory flooring, bench tops, stair treads, truck bodies, paper-mill beaters, agitator bars, and jordan and bed plate filling. Although it was successful in most of these tests, other factors played against its continued use. Cost, seasoning difficulties, machining troubles, and lack of inventories available for prompt shipment forced those who tried it to go back to domestic hickory and hard maple.

Beefwood is used today for arrow footings and billiard cue butts. Its weight of 56 to 75 pounds per cubic foot is a limiting factor in furthering its utilization.

Guayacan

One of these woods is closely related to lignum-vitae and is similar in all its properties except for the oil content. The commercial supplies come from *Bulnesia arborea* occurring on the coast of Colombia and Venezuela (15).

The other guayacan woods are products of the genus *Tabebuia,* principally *T. guayacan* (Seem) Hemsl. and *T. heterotricha* (DC.) Hemsl. They are characterized by having deposits of a yellow, powder-like substance in the vessels called lapachol. In strength and durability these guayacan woods compare favorably with greenheart (3), and may be used for similar purposes.

There are about 12 U. S. importers who list guayacan in their inventories and, according to reports from them, the Bulnesia type is sold as a less expensive substitute for lignum-vitae. Its uses are similar, although it is not regarded as being satisfactory in stern tube ship bearings. The Tabebuia type is sold as a greenheart substitute.

AFRICA

Like South America, Africa has a great wealth of tropical hardwood timbers. The European trade has been using many kinds that are practically unknown on the American market. Africa's west coast has been the scene of most logging activity, with Nigeria and the Gold Coast (Ghana) producing the largest tonnage of logs.

Again like South America, Africa's most important timber export is mahogany (21), but in recent years a growing increase in the popularity of several other woods of the "Dark Continent" has been apparent. Limba (korina), sapele, okoumé, makore, and utile are good examples.

One rather peculiar fact concerning the major timbers of Africa's export trade is that, out of the 12 leading species, not one is heavy enough to be classed as a "high-density" wood. Zebrawood, iroko, movingue, and makoré come close, but a weight of 44 pounds average air dry has been established as a minimum for purposes of this article.

Among the 10 woods classed as "low volume" export species we find only three in the high-density category. The following breakdown provides a close approximation of the current trade picture.

African woods exported to the U. S. in considerable volume:

1. African mahogany—*Khayla ivorensis* A. Chev. (principally)
2. Limba—*Terminalia superba* Eng. & Diels.
3. Okoume—*Aucoumea klaineana* Pierre
4. Sapele—*Entandrophragma cylindricum* Spr.
5. Utile—*Entandrophragma utile* Spr.
6. Makore—*Mimusops heckelii* (A. Chev.) Hutch. & Dalz
7. Ayous—*Triplochiton scleroxylon* K. Schum.
8. Zebrawood—*Microberlinia brazzavillensis* A. Chev.
9. Movingui—*Distemonanthus benthamianus* Baill
10. Agba—*Gossweilerodendron balsamiferum* Harms.
11. Iroko—*Chlorophora excelsa* (welw.) Benth. & Hook.
12. Afrormosia—*Afrormosia elata* Harms

Other species exported in small volume (Woods in heavy type are high density specimens)

1. **African Blackwood**—*Dalbergia melanoxylon* Guill & Perr.
2. **Bubinga**—*Guibourtia tessmannii* J. Leonard
3. Padauk—*Pterocarpus soyauxii* Taub.
4. Bosse—*Guarea cedrata* A. Chev.
5. Tigerwood—*Lovoa trichilioides* Harms.
6. Avodire—*Turraeanthus africana* (Welw.) Pell.
7. **Mansonia**—*Mansonia altissima* A. Chev.
8. **Ebony**—*Diospyros crassifolia* Hiern
9. Emeri—*Terminalia ivorensis* A. Chev.

The three high-density woods in the list above are described briefly as follows:

African Blackwood

The musical-instrument trade has its own name of "grenadillo" for this wood (not to be confused with any one of the woods from tropical America called "granadillo").

It is actually one of the rosewoods *(Dalbergia)* but differs considerably from all other members of this genus. It weighs about 82 pounds per cubic foot. After the first acquaintance with this unusual wood, it is never forgotten. The plum-colored heartwood is so sharply demarcated from the pale

yellow sapwood it looks almost like two different woods glued together.

The logs are very small—seldom over 8 inches—and the wood has a tendency to split badly in seasoning (19). This is typical of practically all the extremely dense hardwoods. They must be seasoned very slowly under moist conditions.

Wood wind instruments, such as clarinets and flutes, require the best blackwood turning squares. Shorter and smaller pieces are used for ornamental objects, mainly turnings, since blackwood is world famous as a turning wood.

Bubinga

For a long time, botanists were unable to come to any agreement on what this wood is, but it has now been determined as *Guibourtia tessmannii*. The wood has been used, in limited quantities, for many years for veneers, turnings, and custom-built furniture. It has a beautiful red color with purplish streaks and a pronounced ribbon grain on the quartered surface. With a weight of 50 pounds or more it qualifies as a high-density species.

African Ebony

A jet black wood from the West Coast, mainly Gaboon, it is a little lighter in weight than Ceylon ebony—63 vs. 73 pounds—and differs in some of its properties. It can be steam-bent very successfully if adequate end pressure is maintained, and it seasons much better than the Ceylon wood (23). It is used in small quantities for turnings, carvings, and ornamental objects.

EUROPE

Our imports of logs and lumber from Europe are so small as to be hardly worth mentioning. French walnut *(Juglans regia)*, also known as English, Turkish, Circassian, and so forth, depending on the origin, is probably the most important, with English brown oak and German beech following. The walnut is used in fine gunstocks and cabinet veneers; the oak in architectural work such as fine church interiors, and the beech for turnery.

ASIA

A large section of the world is included here, but the only timber exports of any great consequence are from the Philippines, Japan, Burma, Malaya, and Borneo.

Leading in both volume and importance is Philippine mahogany. There are two types known to world trade: dark red, consisting of red lauan and tangile, and light red, consisting of white lauan and almon. Annual imports of these two woods in the U. S. has more than doubled in the last 5 years. The present rate in lumber alone exceeds 110 million board feet.

The teak trade, though much lower in volume, is still important dollar wise. Imports of Philippine mahogany, apitong, and teak are more important than all other Asiatic species combined. A breakdown of all the well-known species from the Far East is as follows:

Woods of Major Importance

1. Philippine mahogany—*Shorea, Parashorea, Pentacme* spp.
2. Teak—*Tectona grandis* L.
3. Apitong—*Dipterocarpus* spp.
4. Seraya—*Shorea and Parashorea* spp.
5. White ramin—*Gonystylus bancanus* (Mig) Gilg.
6. Japanese white oak—*Quercus crispula* Bl.
7. Japanese birch—*Betula japonica* Sieb.

Woods of Minor Importance

1. New Guinea wood—*Dracontomelum mangiferum* Blume
2. Paldao—*Dracontomelum dao* M. & R.
3. Boxwood—*Buxus sempervirens* L.
4. Sen—*Kalopanax ricinifolium* (Seem) Mig.
5. East Indian Laurel—*Terminalia tomentosa* W. & A.
6. Palosapis—*Anisoptera thurifera* (Blanco) Blume
7. Bagtican—*Parashorea plicata* Brandis
8. Macassar Ebony—*Diospyros macassar* A. Chev.
9. Ceylon Ebony—*Diospyros ebenum* Koenig
10. Japanese beech—*Fagus crenata* Bl.
11. Camphor wood—*Cinnamomum camphora* Nees & Eberm.
12. East Indian Rosewood—*Dalbergia latifolia* Roxb.
13. Narra—*Pterocarpus indicus* Willd.
14. Andaman padauk—*Pterocarpus dalbergioides* Roxb.
15. Tamo—*Fraxinus mandshurica* Rupr.
16. Japanese cherry—*Prunus serrulata* Lindl.
17. East Indian Satinwood—*Chloroxylon swietenia* D.C.
18. Meranti—*Shorea leprosula* Mig.

Apitong

This is the only important high-density wood from the Far East. The genus *Dipterocarpus* occurs mainly in the Philippines, where it is known in the trade as apitong. There are about 15 commercial species (6), and the range of geographical distribution seems to have some relationship with the density and strength of the lumber. Apitong from the island of Negros, in the Central Philippine area, was substantially higher in density and strength than specimens from either Luzon or Mindanao, according to tests conducted by Timber Engineering Co. in July, 1954 (13). While these tests were limited in number of specimens involved, they have been supported by subsequent tests by Duke University (8), which appear to confirm these earlier indications.

The species *Dipterocarpus grandiflorus* produces the hardest, but probably the best quality commercial timbers. The reddish-brown wood will average about 42 to 46 pounds per cubic foot air dry. It has a number of uses. In the U. S. it is a favorite wood of many trailer truck body manufacturers for flooring. It is also eagerly sought by the producers of electric powerline equipment for crossarms, braces, and so forth. They like apitong because, even though the lumber is all clear heartwood, it is very easily pressure treated. Mine-shaft guides, railroad car decking, residential and factory flooring are other important uses.

Other names for apitong include bagac (trade name U. S.) eng (India), gurjun (Burma), keruing (Malaya), hora (Ceylon), and yang (Siam).

As an Asiatic export timber, apitong is next in importance to Philippine mahogany, although in volume it would only amount to about 5 per cent or 5,500,000 bf. Teak, the next wood in volume, is third with about 1 to 1½ million bf annually.

Among the woods of minor importance, there are several from Asia in the high-density class. These are:

New Guinea Wood and Dao

New Guinea wood is so similar to Philippine dao (pronounced "dow") that they can be treated together here. The lustrous, variegated gray tones streaked with black lines and yellowish hues make these two species outstanding—especially when the logs are quarter sliced. The dry wood weighs as much as 52 pounds per cubic foot.

Philippine dao is by no means plentiful. Good logs are always in demand, and like narra, they are so highly prized by the local industries in the islands that only a few logs are released for export. In many parts of the Philippines, the natives believe that the dao tree, with its enormous buttress, harbors evil spirits and woodsmen are afraid to touch it (16). This may have much to do with the continuous "scarcity" of dao logs on the market.

One of America's largest furniture plants has been making a suite in modern design using dao veneer. It has been a popular item for quite some time. We also find many elevator cars veneered in Guinea or dao. Whenever there is a preference for a dark-colored wood, we frequently find one or the other used.

Boxwood

The true English boxwood *Buxus sempervirens* is indigenous all through southern Europe to the Himalayan mts. of Northern India, but the wood used mainly by boxwood consumers in the U. S. is from Venezuela *(Gossypiospermum praecox)*. The true boxwood does not grow as large nor as free from defects as the South American substitute. The principal uses are for rulers, architect's and engineer's scales, engraver's blocks, and scientific apparatus.

East Indian Laurel

India and Burma are the sources for this attractive veneer wood. Its weight of 43 to 58 pounds is indicative that it is quite hard, dense, and capable of taking a good finish. The wood is light brown with darker streaks running parallel with the grain.

It is seldom used except in the form of veneers for furniture, cabinetry, and architectural paneling.

Macassar Ebony

One of the author's first experiences working Macassar ebony is recalled as a nightmare of sneezing. The dust from sawing or sanding operations irritates the respiratory system of many people. But because of its fascinating color and figure and its great hardness, it holds a certain attraction for people who admire the unusual. Its black wood is streaked with brown or gray, sometimes even orange or yellow, and in occasional logs the figure is so wild as to suggest Italian marble.

The weight of about 68 pounds per cubic foot explains why it must be sawn into veneers rather than sliced.

Only the most expensive architectural installations can justify the high cost of this veneer.

Ceylon Ebony

This appears to be the choice of the musical-instrument industry for making the ebony parts for violins, pianos, and other items in which ebony parts are traditional.

Cheap instruments are now fitted with black plastic parts, but in the best quality lines, ebony is still demanded.

The logs are bought by the pound, and because they are usually so defective, a manufacturer can consider himself highly successful when he can obtain a yield of 30 per cent from a given lot of logs. Yields of 10 per cent are more common. This abnormally high waste makes ebony one of the world's costliest woods.

East Indian Rosewood

If it were not so very dark in color, this wood undoubtedly would find more uses. It is very easy to work, and the dust is not objectionable, but the dark purplish wood looks almost black when any sort of lacquer or varnish is applied.

The greatest difficulty encountered by furniture producers who have used East Indian rosewood has been in matching the color and figure of veneers from one log with another. Most of them give up in despair, the logs vary so greatly.

The wood weighs around 53 pounds per cubic foot, and in comparison with oak it is said to be 30 per cent heavier, yet 2½ times as hard. (23) Although the author's experience with this wood has been limited to only a few logs, none has been encountered in which the wood was as hard as is indicated above.

East Indian Satinwood

This is a pale gold, very hard and heavy wood from Ceylon and So. India. The logs are rather small, and those of good quality are very expensive. Many of the veneer installations in furniture or decorative paneling have developed surface checks. This defect has undoubtedly prevented more widespread utilization. Satinwood has a sweet, coconut-like odor and weighs 61 pounds per cubic foot, air dry. In hardness it is said to exceed mahogany by four times. (23)

Some of the most handsome brush backs are made of satinwood. There are few other uses today for the solid lumber, however. In the form of veneer, its principal use is in borders, inlays, and decorative designs, especially in Thomas Sheraton reproductions. Sheraton probably admired satinwood more than any of the early masters, judging from his originals.

Satinwood has a bad reputation for causing dermatitis among the craftsmen who handle it. Bathing the skin with a solution of borax after exposure is said to be an excellent preventative (18).

OCEANIA

(Australia, New Zealand, Hawaii)

There are about 8 species from this region that are exported to the U. S. in small volume. These are:

1. Orientalwood—*Endiandra palmerstonii* C. T. White
2. **Jarrah**—*Eucalyptus marginata* SM.
3. **Koa**—*Acacia koa* Gray
4. **Ironbark**—*Eucalyptus paniculata* SM. and others
5. Yuba—*Eucalyptus obliqua* L. Hertier
6. Australian maple—*Flindersia brayleyana* F. r. M.
7. Australian blackwood—*Acacia melanoxylon* R. Br.
8. Blackbean—*Castanospermum australe* A. Cunn.

The three woods in heavy type above are in the high-density class. These are briefly described below.

Jarrah

This is one of the most important members of the large and famous Eucaplyptus genus. It is a dense, reddish-brown wood weighing 50 pounds per cubic foot in the seasoned condition, and is noted for its fire resistance. (1)

Hardwood yards on the West Coast usually carry a few thousand feet of jarrah. It is available in large, heavy sizes and satisfies the demand for a durable hardwood in dock and wharf construction. It also finds use in ship construction, mine shafting, and car decking.

Koa

This is the most valuable native wood of the Hawaiian Islands. It is the wood the natives use for their famous ukuleles and ocean-going canoes. (17)

Classed among the finest furniture veneers, koa is used in limited quantities for inlays, marquetry, bandings, and occasionally over entire surfaces. Its rich, lustrous brown color is frequently accentuated by a roey or fiddleback grain.

It is regrettable that koa trees are not found on this continent too; for if the supply were more abundant it could conceivably be as popular as mahogany.

Ironbark

Even well-seasoned ironbark will sink in water, as will several of the other commercial high-density woods previously mentioned.

Ironbark, another of the eucalypts, is a rather miserable-looking timber as seen in a lumber yard, always checked badly on all surfaces, but seldom if ever checked all the way through the piece. The timbers, imported from New South Wales, are large and are used for the same purposes as jarrah, namely heavy West Coast construction projects, wharfs, docks, ships, and so forth.

Conclusions

In conclusion, a few general remarks about the density of wood are in order. One should always deal in *averages* when thinking of weight, strength, and similar properties of a species, and not minimums or maximums. When we think of an ordinary man we don't visualize a 3-foot

midget, nor an 8-foot giant. We think, more likely, of a fellow around 5 feet 10 inches. When we think of balsa wood, we don't think of the very lightest 3- or 4-pound material, nor the heavy 24-pound wood; we are more inclined to think of the 8- to 10-pound wood, which is about average. There are freaks in nearly all woods. In 20 years of wood collecting one is bound to run across some interesting oddities—for example, certain specimens of sycamore, pine, oak, and ash that would all sink in water, while certain pieces of lignum-vitae, ebony, and quebracho that float! With *average*-weight material of these species, the reverse would be true.

In connection with commercial high-density woods, it would be difficult to say whether the demand regulates the supply or the supply regulates the demand; at least there seems to be happy balance most of the time. One thing is quite certain; they have a definite need in American industry.

Literature Cited

1. Boas, I. H. The commercial timbers of Australia—their properties and uses. CSIRO, Melbourne, Australia.
2. Bruce, H. O., R. A. Cockrell, and L. J. Cummings. 1951. Properties and uses of commercially important Japanese Woods. Rept. 147, Natural Resources Section, Supreme Cdr., Allied Powers.
3. Dickenson, F. E., and others. 1949–54. Properties and uses of tropical woods. T.W. Nos. 95, 97, 98, and 99, Yale University.
4. Draffin and Muhlenbruch. 1937. ASTM paper.
5. Eisenchiml and Newman. 1956. The Civil War, Vol. 1, The American Iliad. Grossett and Dunlap, New York.
6. Gerry, Eloise. 1952. Apitong, bagac, eng, gurjun, keruing, yang. Forest Service, USDA, Foreign Woods Information Leaflet, Report 1920.
7. Heck, G. E. 1937. Average strength and related properties of five foreign woods tested at the U. S. FPL. Report 1139.
8. Hug, R. C. 1957. The physical and mechanical properties of certain Philippine woods. Duke University.
9. Keith, H. G. 1947. The timbers of North Borneo. North Borneo Forest Records No. 3, Hong Kong.
10. Kribs, D. A. 1950. Commercial foreign woods on the American market. Penn. State University.
11. Kukachka, B. F. 1956. Palosapis. Forest Service, USDA, Foreign Woods Information Leaflet.
12. Kynoch, W., and N. A. Norton. 1938. Mechanical properties of certain tropical woods, chiefly from South America. Bul. 7, University of Michigan.
13. Micklewright, J. T. 1954. Testing and evaluation of apitong from the Philippine Islands. Proj. 33, Philippine Mahogany Assoc.
14. Moldenke, H. N., and A. L. Moldenke. 1952. Plants of the Bible. Chronica Botanica Oc., Waltham, Mass.
15. Record and Hess. 1943. Timbers of the New World. Yale University Press.
16. Reyes, L. J. Philippine woods. Tech. Bul. 7, Dept. of Agriculture and Commerce, Manila, P. I.
17. Rock, J. F. 1913. The indigenous trees of the Hawaiian Islands. College of Hawaii, Honolulu.
18. Sherwood, M. H. 1936. From Forest to Furniture. W. W. Norton & Co., New York.
19. Spalt, H. A., and W. L. Stern. 1956–57. Survey of African woods. Yale University Tropical Woods, 105–106.
20. Stearns, J. L. 1947. Tropical veneer woods. Wood magazine, p. 23, April.
21. Stearns, J. L. 1948. African veneers. Wood magazine, p. 20, Nov., p. 28. Dec.
22. Thomas, A. V. 1940. Malayan timbers tested in a green condition. Malayan Forester, 9.
23. Anon. 1956. A Handbook of Hardwoods. Forest Products Research Laboratory, Dept. of Scientific and Industrial Research, Her Majesty's Stationery Office, London.
24. U. S. Forest Products Laboratory. 1953. Foreign woods frequently imported into the United States. Report 1940.
25. Harrar, E. S. 1941. Some physical properties of modern cabinet woods: 1, Hardness. Yale University T. W. 69.
26. Swain, E. H. F. 1928. The timbers and forest products of Queensland. Queensland Forest Service.

Forced-Air Drying Pays Dividends[1]

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Net savings on western softwood lumber dried with forced air ranged from $59 to $159 per carload in actual shipping weight reductions. Total equipment cost per unit was $2,300; this has been reduced to $1,700.

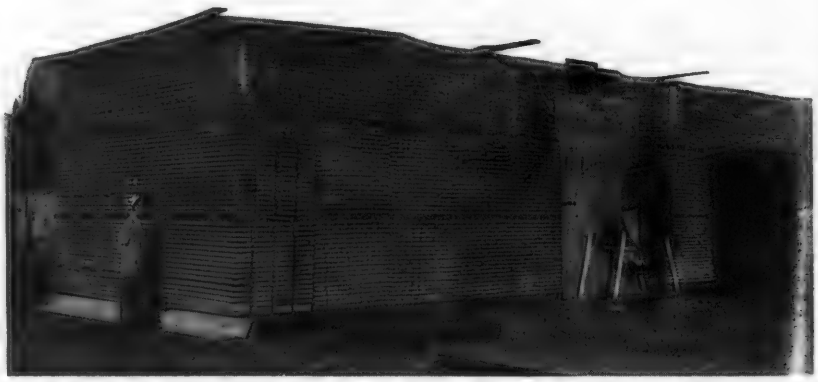


Fig. 1.—Piling method for initial charge; 75 M fbm of two-inch West Coast hemlock lumber.

High shipping costs from rising freight rates, and increased volumes of high-moisture-content lumber from West Coast hemlock and young-growth Douglas-fir prompted study of accelerated air drying of lumber by forced circulation to aid sawmills without dry kilns reduce shipping weights with minimum capital investment.

Economical reduction of weight could lower costs; reduction of moisture content to or below 19 per cent could mean increased selling price, also.

[1] Presented by L. D. Espenas at Session XI, Wood Drying (Applied), FPRS 12th National Meeting, June 22–27, 1958, in Madison, Wis.

Fig. 2.—Piling method for charge two; 105 M fbm of two-inch Douglas-fir lumber.

In the early part of the century, several companies and individuals investigated drying by means of forced-air circulation. Firms such as Weyerhaeuser Timber Co. and McCloud River Lumber Co., and individuals such as Herbert Fryer, constructed installations for forced-air drying. Early conclusions were that this method of drying was economically unsound.

Firms such as Simpson Logging Co. and Hammond Lumber Co. have made recent attempts to dry redwood in this manner. In discussing some problems encountered, they indicated that, while forced-air drying did not have much promise for coastal mills, it did show promise for mills east of the Coast range.

Until 1957, Santiam Lumber Co. was air-drying lumber with forced circulation by a fan system and piling arrangement different than that decided upon for study.

Results of early studies were discouraging, but changing conditions and recent success of the Santiam Lumber Co. encouraged initiation of the present work. Improvements in fan design and lumber handling, increases in freight rates and the fact that much lumber now sawed has a high moisture content, were changes thought likely to affect present results.

Equipment

Drying equipment was fabricated by the Forest Products Research Center and installed at the Santiam Lumber Co. mill in Lebanon, Oregon, in November of 1956.

The Author: Jack Pfeiffer graduated from Colorado A & M in 1947, and received an MF in wood technology from Duke University in 1950. He joined the Oregon Lab in 1951.

The initial set included two 60-inch, 2-blade, propellor-type fans, each driven by a 7½-hp electric motor. Fans were designed to deliver about 50,000 cubic feet of air per minute at a static pressure of about one-half inch. Fans were erected so centers of the shafts were about 6½ feet from the ground, and each was surrounded with a plywood baffle 8 feet wide and about 14 feet high. After the second charge of lumber had been dried at Lebanon, an automatic, hair-element humidity controller was installed to reduce power costs by starting the motors when relative humidity was 90 per cent or less and stopping them when relative humidity rose above 90 per cent.

A portable roof also was provided to protect the lumber from rain. The roof consisted of 4-foot by 12-foot frames of 2- by 3-inch lumber covered with corrugated aluminum. The roof sections were tied to the lumber pile.

Cost of fan units, humidity controller, and portable roofing, including fabrication, was about $2,300.

After apparent success with the first installation in the Willamette Valley of western Oregon, a second unit was constructed to determine the air-drying potential with forced circulation in other Oregon areas. Since static pressure for the first set of fans was about ¼ inch or less, instead of the ½ inch originally thought necessary, 72-inch disc fans were selected, rather than propellor-type fans. The connected horsepower was the same, as also were the portable roof and humidity controller. The cost, however, was about $1,700. The second set of fans was installed at the Eugene F. Burrill Lumber Co. at Medford, Oregon, in March of 1958.

Recording hygrothermographs were installed at the same time each set of fans was set up in the field, to record climatological data and to determine the number of hours fans actually were running at each location. During charges 3 through 6, a hygrothermograph was installed both inside and outside the pile to record temperature and humidity before and after the air passed across the lumber.

A watt-hour meter was mounted on each set of fans to determine power costs and to serve as a check on hours of fan operation indicated by the hygrothermograph charts.

Procedure

An initial charge of about 75,000 board feet of 2-inch West Coast hemlock dimension lumber in 6-, 8-, and 10-inch widths was stacked in two piles according to the arrangement shown in Fig. 1. Polyethylene sheeting was placed over the piles on each side of the fans to shed rain. Wind damaged the plastic sheeting after three weeks, and it was replaced by portable wooden frames covered with aluminum roofing.

The piling method for charge two and all subsequent charges was changed in an attempt to: increase volume of lumber dried, improve uniformity of air velocity, and increase ease in lumber handling.

Fans were spaced about 65 feet apart, and lumber was piled two tiers wide and three units high along an alleyway between the fans, as shown in Fig. 2. The central alleyway was covered with planks and plywood, shown in Fig. 3, and the lumber tiers were roofed with aluminum-covered frames.

Air velocities were measured along the inside and outside of the piles when fans were blowing into the central alleyway, and again when fans were blowing out. Drying was done with fans blowing out, since air velocity through the lumber piles was fairly uniform. With fans reversed to blow into the central alleyway, air velocity out varied from 1,000 feet a minute in the outside centers along the length of the piles, to some movement in at ends of the piles. An undesirable lack of uniformity in drying obviously could result.

The drying rate was calculated from weights of selected pieces in each charge; 17 in charge 2, and 12 in all subsequent charges.

Hygrothermograph data were analyzed, and the number of hours relative humidity was 90 per cent or below, which indicated number of hours fans could have been on, was determined. Costs, however, (Table 3) were based on actual kilowatt hours used. In Fig. 4, temperature and rela-

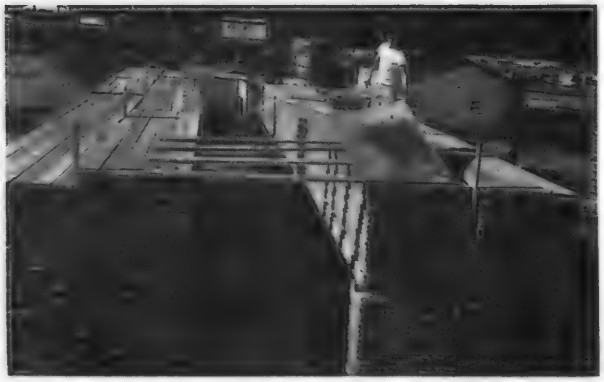


Fig. 3.—Piling method for charge three; 105 M fbm of two-inch Douglas-fir lumber.

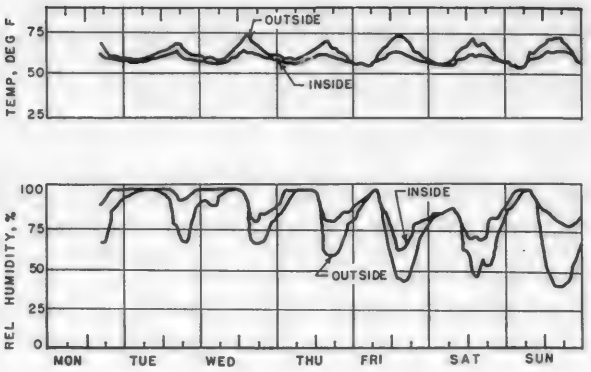


Fig. 4.—Temperature and relative humidity for charge 6, Aug. 5–12, 1957.

tive humidity are given for a typical charge for one week, showing data for inside and outside the charge.

Results

Information on drying nine charges is summarized in Table 1. It is evident that considerable savings in electricity were achieved by not operating fans when relative humidity was above 90 per cent.

Preliminary Charge: The first charge of 75,000 board feet of 2-inch West Coast hemlock was stacked in the manner shown in Fig. 1 for 11 weeks, beginning in November 1956, but the fans operated only 8 weeks. Since the plastic sheeting used as a roof was blown off at the end of 3 weeks, and was not replaced for 2 weeks, the lumber piles were penetrated by rain.

At end of drying, however, the moisture content had been reduced from 66 per cent to a final average of 29 per cent.

The method of piling charge one was unsatisfactory, because long lumber had to be stacked adjacent to the central alleyway, and short lumber near the outside. To remove a pile of long lumber, all short lumber had to be moved.

Air velocities for charge one varied from 50 feet a minute at the outside center of the piles to 2,000 feet a minute on inside edges near fans.

The stacking method for charge one may be desirable, however, during hot, dry weather to prevent excessive checking and degrade.

Second and Third Charges: About 105,000 board feet of 2- by 6-inch and 2- by 8-inch Douglas-fir were in each of the second and third charges, an increase from 75,000 board feet dried in the first charge, due to the improved piling arrangement. The revised piling arrangement (Fig. 2) improved moisture-content uniformity by causing the air to move across a minimum distance of lumber.

Forced-air circulation was started on charge two on March 27 and was stopped April 17, 1957, after 21 days. Charge 3 was started April 18 and stopped May 9; also a total of 21 days.

Notice in Fig. 5 that, during a period of wet, cool weather toward the end of April, the fans did not operate for two days.

Charge Four: Charge four consisted of 125,000 board feet of 2- by 4-inch, 2- by 6-inch, and 2- by 8-inch Douglas-fir lumber.

Forced-air drying was started on charge four on May 20 and was stopped June 10, a total of 21 days.

It is evident in Fig. 6 that the fans operated part of every day, with the exception of May 22.

Charge Five: There were 184,000 board feet of Douglas-fir in charge five, which consisted of 2- by 6-inch, 2- by 8-inch, and 2- by 10-inch lumber.

Forced-air circulation was started June 21 and stopped July 5.

Evidence of good drying weather is shown in Fig. 7. The fans operated more than half the time each day.

Charge Six: About 110,000 board feet of 2- by 4-inch, 2- by 6-inch, 2- by 8-inch, and 2- by 10-inch West Coast hemlock lumber were included in charge six. Forced air circulation was started August 5 and stopped August 26.

Hygrothermograph data in Fig. 8 reflect fast drying conditions.

Charge Seven: Shortly after drying charge six, the fans were moved from Lebanon to Hult Lumber Co., Junction City, Oregon, about 40 miles distant but still within the Willamette Valley.

The first charge at this location (the seventh actual charge) was stacked and ready to dry on November 1. About 92,000 board feet of 1- by 6-inch and 1- by 8-inch western red cedar were included, consisting of both mixed heart and sapwood, and mixed flat and vertical grain.

Forced-air circulation was started November 2 and stopped December 6.

The drying rate was calculated from weights of 12 matched pieces taken from three boards; these were distributed throughout the charge. After five weeks, the moisture content was measured for increment borings from

Table 1.—SUMMARY OF DRYING DATA FOR CHARGES ONE THROUGH NINE

Charge[1]	Volume M fbm	Lumber thickness Inches	Electricity used Kwh	Operating time		Moisture content[2]				Air velocity, range[3] Ft/min
				Fans on Hours	Total Hours	Initial Range %	Initial Mean %	Final Range %	Final Mean %	
1	75	2	17,472	1,344	1,344	43– 85	66	25–43	29	50–2000
2	105	2	1,692	157	500	36– 73	46	20–30	23	300–500
3	105	2	2,272	370	500	31–105	50	19–30	22	300–500
4	125	2	2,596	238	500	28– 55	39	16–22	19	150–350
5	184	2	2,208	229	336	23– 55	34	17–19	18	100–200
6	110	2	3,220	309	500	21–100	73	14–25	19	250–350
7	92	1	4,380[4]	261	840	36–123	74	24–47	28	100–200
8	110	2	8,948	663	1,512	35–178	76	21–52	28	80–300
9	95	1	2,940	218	768	21–156	61	16–27	21	50–300

[1]Charges 1, 6, and 8 were West Coast hemlock; charges 2, 3, 4 and 5 were Douglas-fir, and charges 7 and 9 were western red cedar.

[2]Calculated from weights of selected pieces; 15 for charge 1, 17 for charge 2, 8 for charge 7, and 12 each for charges 3, 4, 5, 6, 8, and 9.

[3]Air velocity for charge 1 based on air-travel distance of about 25 feet; subsequent charges based on air-travel distance of about 8 feet.

[4]Fans operated continuously for more than two days while faulty humidity-control instrument was being replaced. Some recalibration was necessary afterwards.

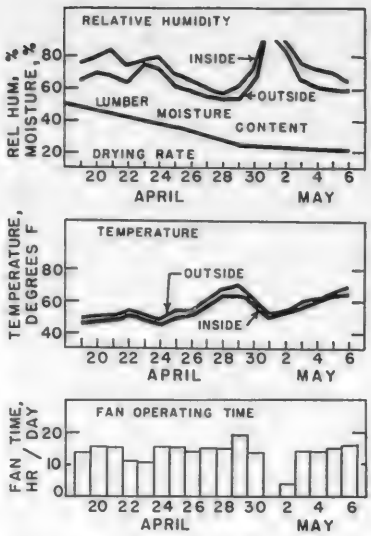


Fig. 5.—Charge 3, operating conditions.

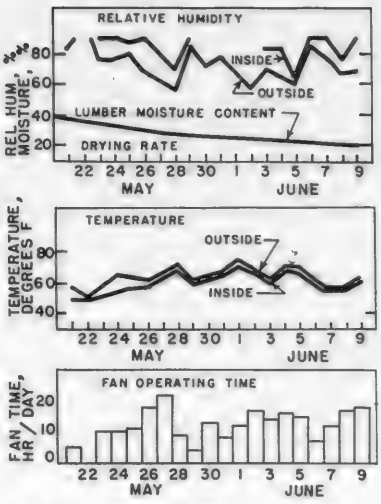


Fig. 6.—Charge 4, operating conditions.

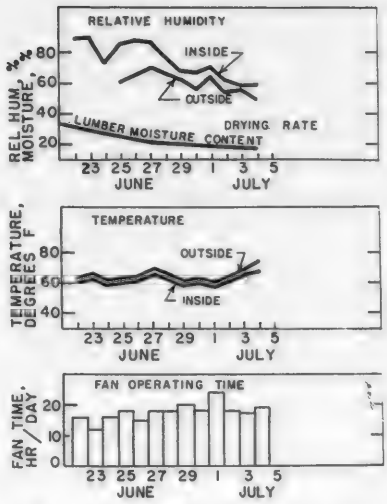


Fig. 7.—Charge 5, operating conditions.

20 randomly selected boards, and 60 additional boards were tested for moisture content with a moisture meter. From these data, the average moisture content was determined to be slightly below 30 per cent.

Heavy boards from sinker logs, one of which was included in the original 12 samples, comprised less than two per cent of the total boards in the charge. It was decided, therefore, to stop air drying the charge at this point, since it would not be worth the additional cost to continue drying until the small percentage of heavy boards reached a moisture content of 30 per cent or less. The entire charge then was kiln-dried with a schedule suited to the average moisture content of the charge, disregarding the heavy boards. Kiln drying was completed in 72 hours, after which the average moisture ranged from 9 to 13 per cent, with a mean of about 11 per cent.

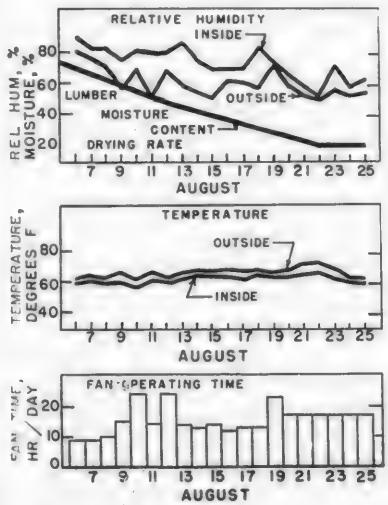
Hygrothermograph data in Fig. 9 show several days when fans did not operate because of high humidity.

Charge Eight: Charge eight consisted of about 110,000 board feet of 2- by 4-inch, 2- by 6-inch, and 2- by 8-inch West Coast hemlock lumber.

Forced-air circulation was started January 15, 1958, and stopped March 19. A few boards in this charge were still quite wet after nine weeks of air drying. Moisture-meter readings on 100 random pieces in the charge showed the average moisture content was still well above 30 per cent, although weight loss of the 12 selected pieces had become stagnant. It was decided to discontinue air drying this charge and start another, since the time of the year was at hand when maximum advantage from forced-air drying could be expected. This hemlock charge was set aside to be kiln-dried later.

As a matter of interest, several of the heaviest boards were selected from this charge, and moisture content was determined by the oven-drying method. The heaviest board was at 166 per cent moisture content. After four weeks inside the Research Center at an average temperature of about 70° F., the moisture content of that piece was still 75 per cent.

Shortly after termination of air drying, this charge was kiln-dried in 36 hours with excellent results. Moisture-meter readings on 100 random boards ranged from 9 to 25 per cent, with a mean of about 12 per cent.



ig. 8.—Charge 6, operating conditions.

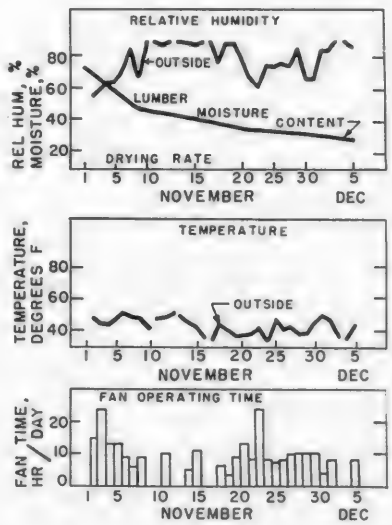


Fig. 9.—Charge 7, operating conditions.

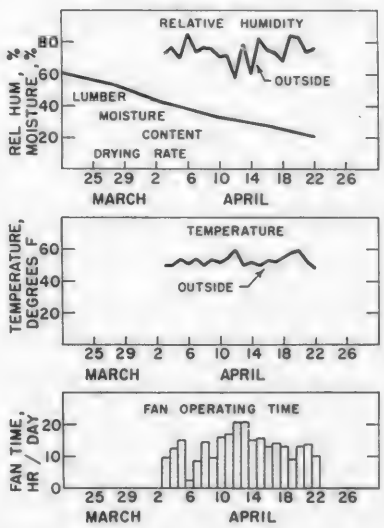


Fig. 10.—Charge 9, operating conditions.

Due to failure of the hygrothermograph, no climatological data are available for this charge.

Charge Nine: About 95,000 board feet of 1- by 6-inch and 1- by 8-inch western red cedar were included in charge nine.

Forced-air circulation was started March 21 and stopped April 22.

Hygrothermograph data for charge nine are shown in Fig. 10.

Charge Ten: Charge ten was the first charge of lumber at the Eugene F. Burrill Lumber Co., Medford, Oregon, where the second set of equipment was installed. Here, fans were the 72-inch disc-type. This charge consisted of about 100,000 board feet of 2- by 4-inch untrimmed white fir lumber from sinker logs. Because the lumber was not trimmed, close piling end-to-end was not possible, and considerable air bypassed the lumber.

Forced-air circulation was started March 26. When this paper was written, drying was not completed. The initial moisture content of 8 selected samples ranged from 45 to 146 per cent, with a mean of about 104 per cent. After three weeks of forced-air drying, the calculated moisture content ranged from 24 to 84 per cent, with a mean of about 50 per cent.

Air velocity ranged from 70 to 250 feet per minute through the load.

Because the charge was not completely dried as this paper was written, hygrothermograph data are not included.

Economic Aspects

A rough indication of economic feasibility can be had by considering obvious costs. Individual operators may have other costs.

In the present analysis, costs have been classified as variable (dependent on drying time) or fixed (dependent somewhat on size of charge).

Costs were based on several assumptions:

- Electricity at one cent per kilowatt-hour;
- Interest of 6 per cent on lumber at $50 a thousand board feet;
- Amortization of equipment over five 300-day years, or $1.53 a day;
- Stickering, 6 man-days each charge at $20 a day, up to 150 M fbm a charge; 8 man-days up to 200 M fbm a charge;
- Lift truck, 8 hours a charge at $4.50 an hour;
- Roof moving, 12 man-hours each charge at $2 an hour; and
- Freight rate of $1.41 per hundredweight.

Costs for drying charges two through nine were determined tentatively as illustrated in Table 2, and are listed in Table 3.

Actual shipping weights of charges two through five are compared in Table 4 with unseasoned weights suggested by the West Coast Lumbermen's Association. Net savings in shipping costs (based on rate of $1.41 per hundredweight) were calculated in Table 4 by subtracting tentative costs of drying from gross savings in shipping costs. Net savings for 2-inch Douglas-fir dimension lumber were estimated to range from $1.87 in charge two to $5.30 a thousand board feet in charge five.

Present Conclusions

Stacking for charges two through seven apparently gave faster, more uniform drying than that for charge 1, and allowed a larger volume of lumber in a charge (Table 1).

Pulling, rather than pushing, air through the piles allowed increased uniformity of air flow (Table 1).

Economic analysis based on loss in shipping weight alone indicates an advantage in forced-air drying (Tables 2, 3, 4).

During portions of the year, profit potential can be increased, since it is feasible to dry lumber to an average moisture content of 19 per cent, and thereby sell softwood lumber on the basis of dry-lumber prices.

A humidity-controlled switch on the fan motors reduced power cost without loss in efficiency, since little drying would occur at relative humidities above 90 per cent.

Drying to 30 per cent moisture content or below is feasible during winter months in the Willamette Valley area.

Discussion

John McMillen (U. S. Forest Products Laboratory): Isn't it true that the shipper pays a penalty for overweight shipments? Shouldn't this penalty also be included in calculating net savings for predrying?

Mr. Espenas: Yes, there is a penalty for overweight shipments based on WCLA allowance for the car.

Mr. Reno: To answer Mr. McMillen, the charge is generally based on the association weight. The shipper loses on overweight, and gains on underweight.

R. C. Rietz (U. S. Forest Products Laboratory): I would like to mention that we are operating a forced-air yard drier at Sauk City, Wis., at the John Sawyer Tie Co. You would be welcome to visit this installation. It is similar to the setup Mr. Espenas has described, but has a permanent roof.

Table 2.—MANNER IN WHICH TENTATIVE COSTS FOR DRYING CHARGE TWO WERE DETERMINED

Item	Cost Dollars
Variable	
Electricity	$ 16.92
Interest	18.06
Amortization	32.13
	$ 67.11
Fixed	
Stickering	$120.00
Lift truck	36.00
Roof moving	24.00
	$180.00
Total	
Per charge	247.15
Per M fbm	2.31

Table 3.—TENTATIVE COSTS FOR DRYING CHARGES TWO THROUGH NINE

Cost	Cost per charge Dollars	Cost per M fbm Dollars
2	$247.11	$2.35
3	262.91	2.50
4	259.72	2.08
5	302.64	1.62
6	263.44	2.39
7	323.35	3.51
8	422.57	3.84
9	283.32	2.98

Table 4.—POSSIBLE RETURNS FROM FORCED AIR-DRYING DOUGLAS-FIR DIMENSION LUMBER

Charge	WCLA[1] green weight		Actual shipping weight[2]	Shipping costs[3]					
				Per car (30 M fbm)		Gross savings (5 minus 6)		Net savings	
	Width	Weight		Green	Air-dried	Per car	Per M	Per car	Per M
1	2	3	4	5	6	7	8	9	10
	In.	Lb.	Lb.	$	$	$	$	$	$
2	6	2,500	2,200	1,058	931	127	4.23	56	1.87
	8	2,550	2,227	1,079	942	137	4.57	66	2.20
3	6	2,500	2,121	1,058	897	161	5.36	86	2.87
	8	2,550	2,142	1,079	907	172	5.73	97	3.23
4	4, 6, 8	2,500	2,084	1,058	881	177	5.90	115	3.83
5	6, 8, 10	2,550	2,060	1,079	871	208	6.93	159	5.30

[1]Shipping weights for unseasoned lumber as published by the West Coast Lumbermen's Assoc.
[2]As reported by Santiam Lumber Co.
[3]Based on freight rate of $1.41 per hundredweight.

Fig. 1.—Bark rossed from the logs in the pond is picked up by a suction fan and deposited 400 feet away for further processing.

Fig. 2.—Outfeed end of the sawdust dryer. Various fractions are moved to their destination by positive-displacement blowers.

Residues from the Sawmill . . .

MAKING SMOKE OR PROFIT?[1] [2]

PETER FIELD
Manager, Ivory Forest Products Co., Dinuba, Calif.

The day is coming when failure to utilize residues will determine the success or failure of a sawmilling enterprise. Many factors will influence the total percentage of residue that can be disposed of at a profit, so management must make a thorough study of potential markets and set up a definite program.

WE CAN NO LONGER JUSTIFY burning any fraction of that wood residue which will return the cost of preparing it for market, plus even a small profit. The percentage of waste utilized will vary from very little to 100 per cent, depending upon geographic location, manufacturing methods, and species of wood. A utilization program must mesh with these factors, and management must make a thorough study to determine existing markets and create new markets for the end products of the previously wasted materials.

The initial question that must be answered is: How much residue is produced and, in many instances, what percentage of this residue is necessary for generating steam and electricity?

At Ivory Pine, all the wastes produced are surplus, since the mill uses purchased utility electricity applied in many instances through the medium of hydraulic fluid. The dry kilns are operated with natural-gas-fired heat exchangers. The heat is conducted directly into the circulated air stream.

Where the Residues Come From

The logs are debarked in the pond by a rossing-type debarker. This debarker not only produces an exceptionally round log, but also mixes into the removed shredded bark the woody cambial zone situated between bark and sapwood.

This mill saws approximately 25 million feet of timber annually, consisting approximately of 70 per cent true fir, mainly abies concolor and magnifica, with the remaining 30 per cent divided unequally between ponderosa and sugar pine and incense cedar.

All of these species, except incense cedar, can be fitted into such normal waste uses as baled shavings, pulp chips, and car strips, but the true firs, because of their lack of inherent pitch and resin and also freedom from odor when thoroughly dry, have a number of special applications. These qualities make fir residue especially desirable as a wood flour in plastic moulding and as a padding in the export packaging of fresh fruit.

Exactly how much waste is available in a plant of this size? The tonnage is quite staggering. Prior to the beginning of a waste utilization program, the following amounts of waste went into the burner for every thousand board feet of logs cut:

1,000 pounds of bark,
1,100 pounds of green sawdust,
1,300 pounds of edgings, trimmings, and slabs,
500 pounds of dried planer shavings and sawdust,
400 pounds of other waste consisting largely of rot debris and chunks.

4,300 pounds Total

In terms of the annual cut of the mill, the burned waste amounted to this:

12,500 tons of bark
13,750 tons of sawdust
16,250 tons of edgings, trimmings and slabs
6,250 tons of dry planer shavings and sawdust
5,000 tons of other waste

53,750 tons Total

Where the By-Products Are Used

Location, the nature of the soil, and the amount of rain fall determine to a great extent possible markets for wood by-products. Dinuba, the town

[1] Presented at the Joint Northwest Wood Products Clinic—Inland Empire Section Meeting, held April 16, 1958, in Spokane, Wash.
[2] Refer also to "Reducing Sawmill Waste 90 Per Cent in Six Years", by E. P. Ivory, Forest Prod. J., VI (8): 279.

The Author: Peter Field holds a BS degree from the University of California, and has been with Ivory Pine since graduation in 1950.

Fig. 3.—Shredded bark is composted in wind-rows such as this. The entire process takes in excess of six months.

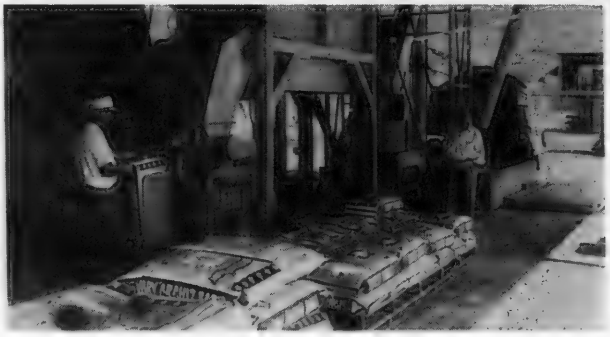


Fig. 4.—Composted bark is either screened or ground here, and is then sacked in polyethlelene-lined bags.

in which the mill is located, is in the heart of the agriculturally rich San Joaquin Valley. The land is largely irrigated with spring and summer runoff waters from the Sierra Nevada mountains to the east. Tulare County, which includes Dinuba, in value of agricultural product is the second wealthiest county in the United States, surpassed only by Fresno County directly to the North and followed by Kern County to the South. The large population and consuming area of Los Angeles is 220 miles to the south, and the San Francisco Bay area is about the same distance to the north. Twelve million people reside within a radius of 250 miles.

The growing and shipping of fresh peaches, melons, plums, and grapes is the largest industry in the area. In loading cars and to protect the fruit from shifting in transit, car strips are used between each verticle layer of boxes. These strips are 4 feet long, 7/16 inch thick and 1½ inches wide. They are made from rather clear edgings and slabs. Last year, over three million pieces of these car strips were produced and sold within a radius of less than 25 miles from the plant.

Pieces unsuitable for car strips and free from bark are sorted for chipping. The resulting chips are blown over 900 feet through an underground 8-inch conduit into open-top box cars and shipped to a large paper company some 190 miles to the north. Planer trim ends and broken boards also go into the chipper. The positive-displacement blower used to convey the chips through the pipe does an effective job of tightly packing the chips into the car. A 200 cubic foot unit of chips will average in excess of 5,200 pounds to the unit, and because of railroad weight limitations, these 50-foot chip cars can only be filled to within 12 inches of the top. Normally, between 180 and 200 cars of chips are shipped annually.

Bark Cinders Were a Problem

The profitable disposition of granulated bark received immediate attention after the installation of the debarker. As long as trim ends and other large chunks of wood were going into the waste burner, the bark would burn with the addition of large volumes of fan-blown air. Even under these favorable burning conditions, a slight breeze would scatter black bark cinders over the country side. This adverse condition was magnified tremendously once the chipper installation utilized the larger pieces of wood waste, and there were instances when the sawmill had to cease production because the burner could hold no more material.

A chemical and fertilizer analysis of shredded bark compared it favorably as a soil conditioner to peat moss. Its fertilizer analysis is as follows:

Nitrogen (N)	0.22%
Phosphoric Acid (P_2O_5)	.20
Potash (K_2O)	.10
Lime (CaO)	1.33
Moisture	.00
Inorganic (Ash)	2.90
Organic Matter	97.10
PH	4.3

In general, shredded bark has these characteristics:

Moderately strong acidity
Low salinity
Low nitrogen availability
High phosphate availability
High potassium availability
Low calcium availability
Low magnesium availability

There are two broad outlets for this bark: the first is in the for of compost for horiticultural, farm, and home use. This fraction has small amounts of nitrogenous material added to it immediately after it is removed from the log.

Composting the Bark

This nitrogen can be in the form of ammonium sulfate, ammonium nitrate, or urea; in fact, any of the common commercial nitrogen fertilizers will do. The bark is placed in wind rows 18 feet wide, 6 feet high and 300 feet long. Within a short period of time, the interior of the bark pile wil reach temperatures in excess of 135° F., regardless of the ambient temperature, as long as the moisture content of the bark does not exceed 80 or drop below 30 per cent oven-dry basis.

Originally, a concentrated commercial strater bacteria was used to accelerate the decomposition action, but it was found that the addition of the starter was unnecessary since sufficient bacteria were already present in the bark and log to initiate the composting process.

Experimentation made it apparent that a supply of additional nitrogen is necessary for the bacteria to multiply and break down the bark into humus. After a period of two to three months, the temperature of the bark pile will slowly begin to drop. At this point, nitrogen is again added and turned into the pile, and the temperature promptly climbs to the original level.

In the past, in order to increase the nitrogen content and add decomposing types of bacteria to the bark pil tons of cull peaches, tomatoes, plums, and even chicken and turkey viscera from the many packing plants in the area were added. This took considerable effort and, in addition, left objectionable pits, seeds, and chicken bones in the finished compost. Currently, nitrogen salts dissolved in water are used, and with this simple process a compost of high humic content can be made in a period of six months. The complete composting reaction is aerobic, and the cycle can be accelerated by frequent turning and aeration of the mass.

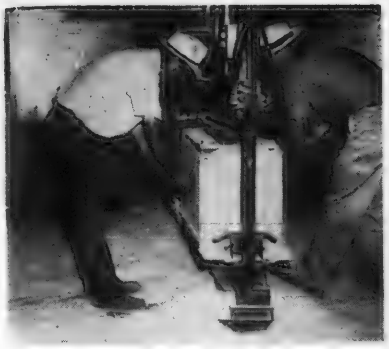


Fig. 5.—Over 3,000 tons of shavings are baled yearly in this machine.

Although the chemical analysis of bark and wood is almost identical, woody particles do not compost so well and so rapidly as does bark.

The composted bark is sold under the trade name of FOREST HUMUS. It is delivered to large commercial users throughout California in bulk by specially constructed, dump-equipped truck and trailer units at about $7 per ton F.O.B. Dinuba. It is also sold through retail nurseries in sacks. This involves a separate and distinct merchandising program involving advertising, dealer aids, and a network of distributors. Naturally, in this form the compost brings a greater return per ton, but additional labor, sacking and distribution costs have to be absorbed.

The question is often asked, "Why is it necessary to compost bark for use as a soil conditioner instead of just using it in its shredded form as it is tossed off the log?"

In its raw or original state, bark has a carbon-nitrogen ratio of approximately 250 to 1. If mixed into the soil, this bark will in time decompose, but in doing so will rob the soil of nitrogen necessary for plant life and cause what is known as soil denitrification. Denitrification is one reason why sawdust is not favorably accepted by growers because, like uncomposted bark, it will retard plant growth for the first one to two years after being put into the ground. After completion of the composting cycle, bark has a carbon-nitrogen ratio in the vicinity of 40 to 1, and when added to the soil in this composted form will help the soil utilize its own minerals, increase in humic content, and hold water for longer periods of time.

Due to the inherent acid nature of bark compost and a moisture content purposely kept high, a polyethylene-lined, multi-walled bag has to be used to prevent the sack from rotting and breaking open during prolonged storage.

Prior to the commercial introduction of bark compost, large horticultural growers and home gardeners in California's alkaline soils used special mixes containing such materials as leaf mold, peat moss, pine needles, rice hulls, and wood shavings for growing acid-loving plants such as azaleas, camellias, and rhododendrons. Using bark compost and deleting all other materials, they are now growing plants that are superior and bloom earlier, and at a reduction in cost of labor and material. The slogan, "FOREST HUMUS brings the bounty of the forest into your garden", is certainly not an over-exaggeration.

Fir Bark for Orchids

During the search for new markets for the composted bark, it was found that some people asked for raw white fir bark, which is the beginning of the story of how white fir bark revolutionized the exotic orchid industry.

In the past, orchids have to a great extent been grown in osmunda. Osmunda is a tightly packed fern root found mainly in New Jersey and Florida. Although in their native environment orchids grow as parasites on tree trunks, bark as a growing medium had been used and discarded by the industry numerous times within the past 50 years. Where the bark of other tree species failed, white fir bark proved to be the ideal potting medium for all orchids. The root system spreads more rapidly, blooms are larger and earlier, watering and fertilizing is simplified, and poor plants perk up immediately when potted in white fir bark.

To date there has not been a scientific reason proven why this bark should be so necessary to successful orchid growing. One theory has been suggested: white fir bark has a uric acid odor and may contain urea that cannot be isolated by ordinary laboratory methods. The cambial zone of the bark and wood of the true white fir is so full of protein nutrients that, when soaked, it becomes gelatinous and similar to the white of eggs. This phenomena has been advanced as another reason for its successful use.

Within a short period of time, 1500 tons of white fir bark went to growers throughout the United States and such countries as Thailand, India, Mexico, and England. The cost of white fir bark was but a fraction of the former material, and gave favorable results.

Every two to three years, mature orchids have to be separated and repotted. Osmunda required the services of highly skilled technicians, and one could repot a maximum of three orchild plants an hour. Repotting in bark can be handled by any laborer in one-third the time.

Bark deliveries within the state, predominately to the Southern California area, are largely in bulk by motor transport, while to the eastern United States and foreign points the bark is packaged in polyethylene-lined sacks and sold under the trade name, IVORY ORCHID BARK.

Sawdust for Fruit Packing

Fruit-packing plants centered within a radius of 30 miles from the mill use up to 3,000 tons of a special coarse sawdust annually. Formerly this was hauled 800 miles to the packing plants. This sawdust cushions and protects grapes going for export shipment, and must be of sufficiently coarse consistency to shake loose and separate from the fruit at final destination. Other requirements of this special sawdust are that 1) it be void of all odors, 2) absorb moisture, and 3) be light in color. White fir meets all these requirements.

In 1957 this market was tapped, but only after the investment of nearly $150,000 for dryer, screening equipment, positive-displacement blowers, and a complete material-handling system. Many early prejudices had to be overcome since green white fir is exactly opposite in its characteristics from when dry. Four years of diligent sales effort were required to break down this deep-seated aversion. Only the sawdust from the head rig and edger can be used so that the greatest amount of fine slivers are eliminated.

From a large, accumulation slab, the sawdust is automatically fed into a 6-foot-diameter, 60-foot-long, low-temperature parallel-flow rotary dryer. The sawdust is dried at an average temperature of 155° F. At the outfeed end of the dryer, an initial cleaning is accomplished by an air separation process, grit and fine sawdust being blown into the burner for disposal. The remaining sawdust passes over separating reels for final grading and packaging into multi-walled paper sacks.

It is necessary to accumulate a large stock-pile of ready-to-ship sawdust, since it is used predominently for Emperor grape packaging, which does not begin until late October and is usually completed prior to Christmas.

Currently, 100 per cent of the green white fir sawdust is utilized, but considerably less of the green fine sawdust from the mill is used. Outlets are increasing, however, and it is believed

that within the year all of it will have been absorbed.

Poultry Bedding from Planer Shavings

The next point is planing-mill waste utilization. In point of time, this was one of the earliest installations at the plant.[1] A conicle screen inside a large cyclone separates the shavings from sawdust and other fine particles. The shavings are then compressed into bales containing 5 cubic foot and weighing 70 pounds each. They are wire-tied and wrapped in heavy kraft paper. The annual production of nearly 100,000 bales of 3,500 tons is used largely for poultry bedding, with small amounts going to dairymen and nurserymen. These shavings yield a return of close to $16 per ton at a cost of $8 per ton. This compares very favorably with a briquetting operation. Species of wood does not matter but, in general, incense cedar is less desirable than either pine or white fir.

The separated sawdust is graded for a variety of uses such as sweeping compound, butcher floor covering, fiber for prepaid roofing, bean cleaning, and as a mud in oil-well drilling. A portion of the white fir sawdust is ground into wood flour of a consistency of 70 mesh and finer. It is used predominently in the Southern California area as a base in plastic moulding. Approximately 90 per cent of wood flour and 10 per cent of resin are mixed for moulding such articles as toilet seats, telephones, lazy suzans, and other objects of this type. White fir, again, is the preferred material because of its lack of resin and ease of grinding.

Little is Left

What does this leave in the way of waste that must be burned? There are slabs and edgings to barky for pulp chips and to short and knotty for car strips. There are coarse chunks, pockets of rot, sweepings from the floor, and dirty fractions from various by-product operations. Gradually, new outlets are being found for each of these. For example, the barky edgings of white fir can be ground into fruit-packing sawdust.

On days when white fir is cut, the total waste burned may be less than five per cent. When incense cedar is cut, on the other hand, the percentage may rise to 25. The fact that none is burned for fuel, however, makes this an accomplishment toward which sawmills must aim. The day is coming when failure to make use of residues will determine the success or failure of a sawmilling enterprise, and even the use of residues for fuel will be as inexcusable as the dissipation of natural gas in oil fields some years back

SEVEN WESTERN EXPERTS DISCUSS

Quality Control in Composition Boards

1. Statistical Quality Control in Particle Board Production

D. E. Isaacson

Particle Board Superintendent, Coos Bay Branch, Weyerhaeuser Timber Co., North Bend, Ore.

To assure a high-quality product, Weyerhaeuser Timber Company has adopted the application of statistical methods in the manufacture of particle board at the Coos Bay operation. Since production of this type of board is a relatively new field of industrial activity, quality control is a practical and technical guide to the methodology and application of necessary production principles.

Statistical control in the production plant was directed at reducing or narrowing the limits of variables that influenced board quality. The firm found that in using these controls it was possible to raise manufacturing specifications and assure a more competitive product.

Initial attempts were directed at the variables attributed to the raw material, which is green Douglas-fir planer shavings. Data were compiled for chip moisture content, particle size, and mat moisture content. Research on the operation of equipment was also conducted and all variables were listed.

While studying the operation of various machines it was learned that the plant could operate at capacity and gain increased quality by maintaining a proper ratio between each device. This led to high production and, as a result, lower maintenance costs.

Any type of statistical control is based on frequency distribution in a process, so a histogram of each variable was drawn up from collected data. Frequency curves were sketched to aid in determining skewness and when causes were determined, corrections were made. As additional data were collected the curves approached normality. This came about in many ways. Operators were more conscious of maintaining closer controls because they were required to plot individual readings. As additional data were plotted, the variables resolved themselves into definite patterns of influence.

The object then was to balance these variables to produce a quality panel of core-type particle board. When control limits were established, each operator made an attempt to keep his machine in top operating condition to follow as close as possible the established average. With this method of charting, it was possible to develop a keen competitive spirit throughout the plant, with higher quality and less downtime due to improper control.

The charts originally had limits set at three standard deviations, but as difficulties were overcome the range fell below two standard deviations. It was then necessary to recalculate and discard quite a number of old values to arrive at a new limit of three standard deviations.

Laboratory test results for modulus of rupture, surface screw-holding and internal bond were plotted. Trends of these values tied in directly with trends in production-line variables. Careful studies were made to learn the effect of changing various relation-

[1] Presented at the Annual Meeting of the Pacific Northwest Section, held Feb. 4-5, 1957, in Tacoma, Wash.

ships. As approved changes in processing were made, new data were collected and charts corrected.

Maintenance of control charts when changes in processing are made is important. In synthetic board manufacture, it is often difficult to determine the advantages of small changes even though they may be considered a safety factor in processing over a period of time. Control charts will indicate whether the change is desirable or undesirable. Too often only the first few readings are noted, which are not sufficient information to use as a basis of control, and a favorable improvement might be dropped without a fair trial.

When process control by statistical methods was put into operation, the production supervisor could study the control charts and gain an immediate and comprehensive picture of the operation without measuring the components from each machine. Failures in machines that can cause process problems further along the system are noted, and necessary corrective measures are taken before material reaches this point.

From the quality and production standpoints, it has been found that the application of statistical quality control is an important step in the control of variable costs.

Control measures can be maintained for any desired number of production variables. Although each industry is different, quality control can be adopted to gain an immeasurable amount of knowledge and thus aid in producing a superior product at a minimum cost through more effective management.

Discussion

Anon: To what level of management is quality control reported?

Mr. Isaacson: On the shift, reports are made to the superintendent, and he, in turn, reports higher up.

2. Commercial Standards and Product Specifications

B. S. Bryant
College of Forestry, University of Washington, Seattle

The particle board industry is working in the direction of a commercial standard for certain of the key properties of particle board such as density—or specific gravity—per cent water absorption, screw-holding capacity, internal-bond strength, modulus of rupture, and, perhaps, modulus of elasticity. Even if such a standard is not forthcoming in the immediate future, certainly one of the problems that every particle board manufacturer faces is the problem of an adequate product specification that carries with it a certain guarantee of performance within carefully established limits.

A standard or specification must have sufficient meaning in it to enable the customer to know what his protection is, how he should evaluate the product, and how he goes about the procedure of reinspection to provide a basis for a claim. The manufacturer must know what the probability is that boards outside specification will occur, or, in other words, he must know the accuracy of the product specification limits.

The whole problem of establishing industry commercial standards as well as company specification limits is related to: (a) the method of sampling the product in the plant, (b) the inherent variability of the product and process, and (c) the degree of statistical control in the process. Let us consider these three items in order and, finally, relate them to a valid method for determining standards and specifications on a product.

Sampling Techniques

Frequency of Sampling: Any supervisor of a forest products manufacturing process who is interested in quality control inevitably faces the question of: How often should I sample? This question answers itself once the process is in control. In the early days of manufacturing, or in a process that is not in control, one may wisely decide to sample frequently, perhaps by sampling one board per press load. Later on, the intensity of the sampling can be reduced to perhaps two or three board samples per shift. In the ideal state, perhaps one sample per shift will be sufficient.

Randomly Selected Samples Are Important: For the sake of simplicity, assume a sampling scheme that involves the selection of one panel per press load. Most would agree that this one panel should be randomly selected, perhaps by drawing a numbered marble out of a container, to determine which opening will contain the sample board.

How to Test the Board so as Not to Destroy It Completely and Still Get Representative Results: This is a practical problem with which the manufacturer must contend. A practical suggestion is to cut back one foot from each end of the board sampled, and cut the specimens for testing from the one-foot end-strips. If a density specimen is to be combined with, perhaps, a swelling and water-absorption specimen, one six-by-six-inch specimen would be cut from both side portions, and one from the center one-third portion, of each of the two end-strips cut from the sample board. This gives a total of six specimens per board (three from each end).

Before one uses the end sampling technique, tests for significance should be made to determine whether the ends of the board are representative of the density of the rest of the board.

Even if the process is under control to the point where the average specific gravity of all boards produced is 0.65, for instance, one cannot expect the average of each of the six specimens for each board tested to hit 0.65. They will probably vary within reasonable limits on both sides of this figure because of natural variation between boards, and natural variation within boards.

Variability of the Product

It seems reasonable to expect a specific gravity range within a four-by-eight sheet, with two-by-three-inch specimens, of 0.15. This means that, for a 0.65 average board, the range of the individual specimens will be from 0.58 to 0.73. Compared to the variability faced by a timber cruiser in the field or a timber mechanics technician in the laboratory, this coefficient of variation of about 4.6 per cent looks good.

By means of short-cut statistical procedures, it is quite possible to convert the range value into a standard deviation. If a specific gravity range of 0.15 (that is, the difference between the highest and lowest values) represents the average range for a number of boards, and the range of each board has been calculated from a sufficient number of two-by-three-inch specimens cut from it (assume, for simplicity, 100 specimens per board), the standard deviation may be calculated readily by taking this average range value, 0.15, and dividing it by 5.00.

In this case, $\frac{0.15}{5.00} = 0.030$, the standard deviation[1]. The coefficient of variation is simply the standard deviation divided by the over-all average for the boards. If the average specific grav-

[1] This is from Table B in *Statistical Quality Control* by E. L. Grant, McGraw-Hill, 1952, for constants for converting average range to standard deviation.

ity of all boards is 0.655, the coefficient of variation equals the standard deviation, 0.030, divided by 0.655, or 4.6 per cent.

By applying simplified normal curve inference to these data, 95 per cent of the specimens cut from any one board should fall between 0.655, the average, $\pm 2 \times .030$, the standard deviation.[2] These limits become then 0.595 to 0.715.

An important question is, what is the variability between boards of a controlled process using a one-board sample cut up into six specimens per board?

This can be answered by the use of another rather common statistical unit of measure called the standard error of the mean, $\frac{s}{x}$. The standard error of the mean, $\frac{s}{x}$, equals the standard deviation, σ, divided by the square root of the number of specimens per board. In this case $\frac{s}{x} = \frac{\sigma}{\sqrt{n}} =$ 0.030 divided by $\sqrt{6}$ (0.030 $+$ 2.45 $=$ 0.0123). The limits within which we would expect single-board-sample averages to fall 95 per cent of the time would be $\overline{\overline{X}} \pm L$; where $\overline{\overline{X}}$ is the true average of the production boards (assume 0.655). Then the limits within which the sample (individual board) averages should fall would be[3] $\pm L = t\left(\frac{s}{x}\right) = 2.57$ (0.0123) $=$ 0.032. 0.655 $\pm$ .032 $=$ .687, or .69. 0.655 $-$ .032 $=$ .623, or .62.

Sample averages (six specimens per single-board sample) might vary between these limits if plotted over some interval of time on a conventional statistical quality control $\overline{\overline{X}}$ chart. Short-cut techniques for calculating production quality control limits are available in a reference on statistical quality control.

In a controlled process, the limits calculated as above could be the specification limits for the board and could be written into a commercial standard or a guarantee in the form of a product specification, provided that the method used for the establishment of the claim in a reinspection procedure were based on the same sampling scheme (that is, three pieces from each end of each board). If desired, the limits could be broadened by using the appropriate value for t which would include 99 per cent of the boards manufactured instead of 95. However, a per cent defective of five is normal for industry.

Necessity for Statistical Control

Product specifications and commercial standards are meaningless unless the processes involved are under statistical quality control surveillance or unless the limits established are so broad as to include almost any board manufactured, whether or not the process is under control.

The quality control chart has been found to be an admirable tool for detecting difficulties within the plant operation before they become serious enough to throw the entire process out of control and thereby nullify the specification limits on the product. Workers who are skilled in the interpretation of control-chart information can detect difficulty in the process long before it becomes serious and take immediate steps to correct it.

[2] This follows from the infallible rule that, in a normal distribution of data, about 95% of the values fall within $\pm$ two standard deviation units from the mean.

[3] The value t is a probability factor that adjusts for sample size; in this case "t" is the value for a sample made up of six specimens ($n - 1 = 5$ degrees of freedom) and a probability of 95%. See Table I of Brownlee, *Industrial Experimentation*, Chemical Publishing Co., 1949. Chapter III is also pertinent.

3. Quality and Process Control in Hardboard Production

W. J. Runckel
Hardboard Div., Oregon Lumber Co., Dee, Ore.

There are a number of tests that may be applied to hardboard pulp as a guide to operation as well as subsequent tests made on the finished product. Among the tests used are the observation of the pulp under a blue glass in a dilute solution. An experienced operator uses this to good advantage. The Oregon Lumber Co. also use freeness testing as a guide to drainage. The Bauer–McNett Classifier is used to isolate the various fractions and show the amount of coarse fraction present. All these tests used together provide the operator and foremen with tools to improve and maintain quality fiber.

On the finished product, foremen in the Oregon mill run such tests as modulus of rupture and two-hour water absorption prior to humidification. Two samples per shift are taken from the humidifier and sent to the laboratory for testing of modulus of rupture, water absorption, density, caliper, lineal expansion, and moisture content.

The testing program is supplemented with daily records at all points throughout the plant. Records of immediate value are taken throughout the mill at the production points. Among these are:

Raw Material: The mill operates on a changing raw material, which comes from an adjacent sawmill. Sawmill cuts are used daily as a guide to raw material used. On these, moisture content, chip analysis to size, and percentage of bark to wood are determined.

Pulp Deck: Records of immediate value would include pressure gauge readings on the Asplunds, volume of chip feed, ammeter readings on the motors, plate settings on the Asplunds and refiners, water to the refiners, pH of stock at various points as well as resin, size, and acid additions.

Forming Machine: Records are kept on machine speeds, ammeter settings on press rolls, roll clearances, mat caliper, etc.

Hot Press: Steam pressures, temperature, press cycles, and volume through put are recorded.

Surface Grading: All boards are surface graded on leaving the hot press. Here it is stamped on the screen side to identify and tie the records to the quality control. All damage caused by equipment or processing may immediately be observed and steps taken to correct it.

Humidifying: Temperature, humidity, and volume input are recorded.

Tempering: All prime grade material goes into this unit. Records are kept on oil pickup, temperature of dipping, baking cycles, humidification cycles, and grade recovery.

Hardboard Processing: Records are kept on grade recovery and process volume through the various units daily. These records help complete a program of efficient utilization.

Laboratory: Data are assembled daily on laboratory results. Since all shifts are coded, these data are essential in releasing material to the finishing department. If material fails to meet specifications, it is downgraded and used where its end use will make it satisfactory.

These records and tests are assembled daily for review. Each morning, results are reviewed by the foremen, superintendent, control director, and manager. Basically this is the control program. Its effectiveness and utility increases as its use continues.

4. Water Absorption and Dimensional Changes of Hardboard

J. W. Johnson
Timber Mechanics, Oregon Forest Products Research Center, Corvallis

THIS PAPER IS BASED on a comprehensive study of hardboard, "Dimension Changes in Hardboard from Soaking and High Humidity," by J. W. Johnson, Oregon Forest Products Laboratory Report No. T-16, May 1956. Thirty-six types of commercial hardboard furnished by 11 manufacturers in the United States and Canada were included in the tests.

Five 3- by 12-inch specimens from each of the 36 types of hardboards were exposed to 24 hours of water soaking, and five similar specimens were exposed to a relative humidity of 90 per cent for 8 months. This summary will deal with results of the water soak test, only.

The soak test was carried out in still water maintained at 70° F. The specimens were placed horizontally in the pans and covered with one inch of water. Average moisture content of all hardboard, before soak, was 3.5 per cent. Water absorption, thickness swelling, and linear expansion of each specimen was determined for soaking periods of ½, 2, 5, 7, 12, and 24 hours.

Conclusions of the Study

All the boards absorbed water at about the same rate during the 24-hour water soak, provided the rates of absorption were based on percentages of total water absorbed. Therefore, water absorption from a 24-hour soak test could be predicted quite accurately from a short soak test.

Straight-line relationships between percentages of water absorption and thickness swelling were found to exist for most of the boards subjected to the 24-hour soak test.

Although several boards showed straight-line relationships between water absorption and linear expansion during the soak test, relationships for most boards were curvilinear and more variable than those evidenced by water absorption-thickness swelling results.

It is important to employ standard conditions both before and during tests when attempting to compare the results of different soak tests.

Discussion

Mr. Wyman Williams (Columbia Hardboard Co.): What is the effect, percentagewise, of temperature of water and initial conditioning of hardboards on water absorption in the 24-hour soak test?

Mr. Johnson: We conducted tests on eight commercial hardboards using water temperatures from 40 to 100° F. From 40 to 60° F. there was little change in water absorption, but from 60 to 100° F. the water absorption for all boards increased appreciably. The rate of change varied from board to board, with the lowest change being about 0.14 per cent and the highest about 0.62 per cent per degree rise in temperature.

Your question regarding effect of initial conditioning on results obtained in a water soak test is answered in the published report. In the study just reported on, the moisture content of the specimens before soak was approximately 3 per cent. In a previous study, we had occasion to soak some of the same type hardboards that were conditioned to 6 per cent. If water absorption results after a 24-hour soak were based on an oven-dry basis, the percentages of water absorption for the hardboards used in the two studies were practically identical. If, however, the percentages were based on initial moisture contents, there was about 3 per cent difference between the two samples, similar to the differences before soak.

Dr. J. d'A. Clark (Consultant): I know of two pieces of work on other water soak tests. One, done during World War II, had to do with correlation of 24-hour soaking and soaking at an elevated temperature of about 135° C. This technique may offer an avenue for still shortening the time required for a water soak test. The other piece of work dealt with differences in results apparently obtained because there were differences in the hardness of the water used for soaking. I suspect that the characteristics of water used for the water soak test would have an important bearing on the results of such tests, and one should be very careful about the kind of water used.

Mr. Johnson: I believe you can vary water absorption (from a 24-hour soak) considerably just by the different conditions used in the test and before the test. We already know that initial conditioning of boards and water temperature affect results. Probably there are other things that affect results, too, such as pH of water, or running water as compared to still water. But if water absorption is based on the water taken up at the end of 24-hours, and if all boards are treated alike before and during the test, all of them will absorb water at approximately the same rate.

I question whether the water soak test is a good test. A "good" or "bad" board (depending on how a person might classify it) from the soak test showed up similar to the others in the humidity test, and the humidity test seems to be a more practical test. In ten days' time in the humidity test, all the boards reached about the same moisture content. This is shown in the report, which can be obtained on request from the Oregon Forest Products Laboratory.

Anon.: Was there any correlation between water absorption in the soak test and in the humidity test?

Mr. Johnson: In this study there was enough information available for many correlation studies. We only put in the report what we considered the most important. We did not correlate water absorption resulting from the two tests for all the boards, but we did for some. The report gives one graph showing this relationship for five boards produced by the same company. These particular boards showed good correlation of water absorption by the two tests. Probably several other types of hardboards would show a good correlation, also.

Dr. Clark: Were the boards conditioned in high humidity for a very long period of time?

Mr. Johnson: The boards were in the 90 per cent relative humidity room for at least eight months, and most of them nearly nine months. Occasionally, the specimens were shifted in location to give each board the same chance in case conditions were not the same throughout the room.

Dr. Clark: By and large, if you know the hygroscopic characteristics of the ingredients of the board, you can almost figure out what they are going to be measurably, and there should be a direct correlation between ultimate moisture content on a high humidity test and what a water soak test will give you. There is correlation, a sort of incidental one; but I believe there would be nothing significant about it.

Mr. Johnson: The interesting thing to me was that all hardboards came to about the same moisture content within the relatively short time of ten days. It is similar to putting wood in certain conditions of relative humidity. It eventually comes to the same equilib-

rium moisture content. According to this, in practical use the boards would reach the same moisture content in a relatively short time, so of what use is the water-soak test in trying to pick out the type of hardboard that will absorb the least moisture?

Mr. W. J. Runckel: None of the producers are satisfied with the water soak test, but it is a test that is in the specifications, and it is something that is difficult to remove. Eventually, I think it will be removed from the specifications and will be replaced by the linear expansion test and thickness swelling test.

Mr. Tower: I think there is a place for the water absorption test, whether a 2-hour or 24-hour one. In those uses where absorption of free water is important and where board may be exposed to water for a short time, then the test may show something, but if you are trying to correlate it with what happens in humidity, then it doesn't have any bearing.

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5. Frequency Distribution, an Aid to Control

N. J. Briggs
Weyerhaeuser Timber Co., Klamath Falls, Ore.

A QUALITY CONTROL PROGRAM is generally regarded as having three main divisions: inspection, prevention, and assurance. Assurance is the newest and probably the least known of the quality functions, yet it can be the most important. It includes such things as conveying information to foremen and management as well as conveying information back to the system itself. It involves the use of statistical analyses, interpretation of data, keeping of records, check inspections, historical knowledge, and knowledge of just what the customer wants. The type specification that clearly states permitted limits would seem to require little assurance when the measured properties fall within these limits—but how adequate is the sample? A hardboard or particle board plant cannot have 100 per cent sampling. The assurance function should answer the question of adequacy of sampling. Some specifications are of a type where the human factor is an important element, and assurance is certainly needed there.

A product can be produced within specification limits for a particular quality, yet when it gets to the customer, a complaint comes back. Prevention of this situation might come under the heading of "continued assurance of uniformity." With the variation of hardboard and particle board physical properties as wide as it is, continued assurance of uniform quality is best provided by means of the frequency distribution.

The Control Chart

A quality control program does not attempt to prevent changes, but only attempts to limit them. No two boards are ever alike, and variations are always present. Control limits may be established inside the specification limits, and properties are allowed to vary at will within these narrower control limits. Process change might be made only when a tendency to exceed control limits is noted.

Few products have properties that fall within control limits 100 per cent of the time; but even for those that do, there are assignable causes of variation not due to chance alone that cannot easily be detected by the control chart, since quite often abnormal variations go unnoticed when they are part of a large number of measurements. The simplest and most readily understood method of analyzing variations is a study of the frequency distribution.

Frequency Distribution

Almost everyone familiar with a control system knows the form of the frequency curve. If one desires to study the performance of a certain property for a period of time (possibly one month of six months), the actual values from the control data are plotted on the horizontal axis and the frequency, or number of times each value occurs during this period, is plotted on the vertical axis. For much of the data, a phenomenon known as *central tendency* will be apparent. The measurement of this grouping of high values in the center of the chart is one of the most fundamental measurements in statistical analysis.

There are certain calculations for use with data covering a wide range to determine the number of cells, cell width, grouping factors, and so forth, but generally this can be simply done. For example, if flexure values are to be plotted, they can be rounded off to the nearest thousand and grouped in cells at one thousand increments. The plotting of almost all data encountered in a hardboard or particle board plant should be no more complex than this.

Frequency Distribution As A Means of Control

If the property values of a product (or a series of products) covering a given period of time are displayed in the form of frequency curves, varying shapes and positions are sure to be produced. The shape and position of each of these has a certain significance.

The symmetrical shape of Fig. 1 would indicate that there are no process variables out of control that would tend to produce erratic, high or low values. The average value lies midway between the limits, indicating that the aiming point of the control system is correct. The range of values is low, which means that no process changes need be made to reduce this range. This situation seems almost ideal, but it does exist. If the resistance to abrasion properties of certain types of board were plotted, a curve similar to Fig. 1 would be formed. When curves of this type are produced, the frequency of sampling can generally be reduced.

Another curve of this type is shown in Fig. 2. This pictures the distribution of flexural strength values. It has been recommended that the specification limits be placed no closer to the average value ($\overline{X}$) than three times the standard deviation to assure conformance. It is surprising how closely the properties of the different thicknesses of board will follow the pattern, and it can be readily seen that a non-conforming value usually would be caused by a processing variable out of control.

A distribution of the form and position of Fig. 3 represents a product that conforms with specifications, but

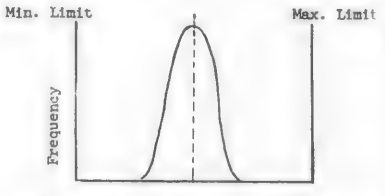

Fig. 1.—Process variables under control. Product meets specifications (or lies within control limits).

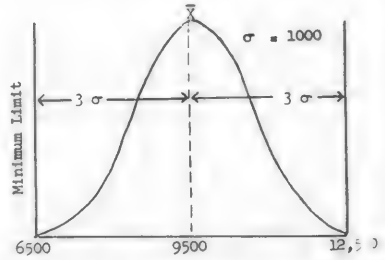

Fig. 2.—Flexural Strength.

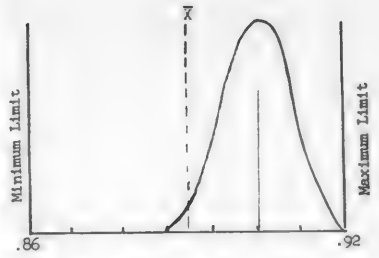

Fig. 3.—Specific Gravity.

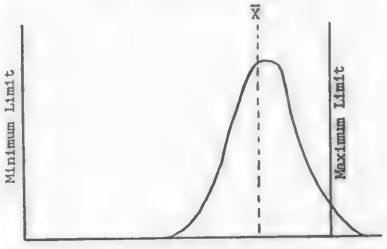

Fig. 4.—Process variables under adequate control, but product does not meet specifications.

non-conforming values are imminent. Quite often when a curve in this position is produced, it is due to intentional misplacement. In Fig. 3 it could be that process variables are causing inferior values of other qualities, and the most obvious correction would be an increase in density. The values conform and the range is low, but the frequency of sampling should not be reduced. If it is necessary that the curve ride in this position, then the limits should be changed.

The distribution of Fig. 4 might represent any property. The shape of the curve and the range indicate that process variables are not fluctuating widely. They may be considered as under control, but with product limits outside the specification. If it does not seem possible to shift the average value back to near the mid-point between specification limits because of economic reasons, effect on other properties, or equipment limitations, then it is probable that the only approach is to accept this average and shift the specification limits to be compatible with these values.

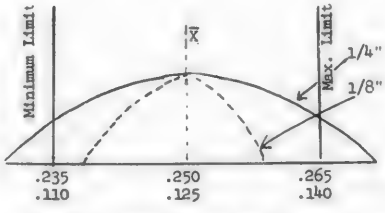

Fig. 5.—Process variables not under adequate control. Products does not meet specifications.

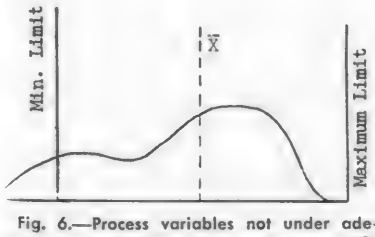

Fig. 6.—Process variables not under adequate control. Product does not meet specifications.

The solid line of Fig. 5 represents a property that is not meeting specification primarily due to wide range. Correction would be a closer control or a tightening of limits of processing variables to narrow the range of values. If the solid line represents the thickness of ¼-inch board, it would be expected that the thickness curve of ⅛-inch board would follow the dotted line if variation in thickness were due to cumulative effect of thickness alone. If the range of thickness of ¼-inch board is not twice that of ⅛-inch board, then the thickness variation is not due to change in thickness from ⅛ inch to ¼ inch, and some item out of control is indicated. It may be that speed control is lost at high (or low) wire speeds because of wire slippage or for other reasons.

Fig. 6, which may occur in many similar forms, is quite common. It generally means that there has been an abrupt and permanent, or long term, processing change during the period of measurement. A change in raw material or usage might result in this type of curve.

Other Uses of Frequency Distribution

In addition to the foregoing, the frequency distribution may be useful for the following:

1. *To reduce paper work.* One of the mistakes that a quality control system can make is the production of too many charts and tables. Important information can become buried and not receive the attention it deserves. For this reason it is better if frequency distributions are plotted representing considerable periods of time. The time and expense required to plot these data can be justified by a consequent reduction in testing that should be indicated. There is little point in continually and frequently testing for a property that cannot be brought under control. Also, there is no need for maintaining a high frequency of testing for a property that is behaving well.

2. *To set control limits at optimum points.*

3. *To prevent long-term drifting.* If the performance for a given period is shown by a frequency diagram, then the performance data for the next period should form a similar chart (unless improvements are made) if tendency toward drifting is to be avoided. This, as previously mentioned, is to provide continuous assurance of uniformity.

Summary

Methods of correcting deficiencies pointed out by frequency diagrams are:

1. Too wide a range can be corrected by closer control over processing conditions.

2. Position of the average value can be changed by change in processing conditions.

3. The symmetry of a curve indicates whether or not a variable is temporarily out of control. This variable should be sought whenever skewed curves are obtained.

4. If range or position cannot be improved by the above methods, and non-conforming material is produced, the only recourse is to widen or relocate the specification limits.

Discussion

Mr. K. Guenther (Pope & Talbot Lumber Company): Did you say that if you have a normal variation, or variations, in a ⅛-inch board, and that if you put two of them together, one on top of each other, it would double the variation?

Mr. Briggs: I did.

Mr. Guenther: Don't you have a compensating effect? If you have one nominal thickness, in which some boards are high and some are low, then a series may level out because there will be thick and thin boards within each series.

Mr. Briggs: Variations that are characteristic at the press or platen-caul assembly will not tend to compensate. Variations caused by felting or forming characteristics may tend toward a compensating effect, but the thickness variation from board to board should increase with increase in thickness.

J. R. Stillinger (Cascades Plywood Corp.): It depends upon whether you are speaking about within- or between-board variation. If you are talking about the within-board variation, and you stack the boards, the maximum points will build up. Between-board variation is something else. There are the two sources of variation, which we tend to overlook sometimes.

6. Slide Rules for Quality Control

J. R. Stillinger
Technical Director, Cascades Plywood Corp., Lebanon, Ore.

Many quality control tests require some type of mathematical calculation to obtain the desired index figure. These calculations can be performed by four different types of calculating equipment, the "pencil and paper" or "long hand" method, several types of calculating machines, alinement charts, and slide rules.

It is comparatively easy to demonstrate that serious consideration should be given to the use of slide rules in quality control calculating work when cost, time, accuracy, and training required to operate the calculating equipment are considered.

The following is a simple procedure for the construction of a slide rule. Included are only those basic mathematical principles that are needed to accomplish the objective of building a slide rule for any mathematical equation. The basic strength equation for calculating modulus of rupture has been arbitrarily selected for the following reasons: it involves more than two variables; it includes both multiplication and division operations; it contains one variable with an exponent other than 1; it includes constants; and finally it is a common expression used frequently in evaluating a physical property of many wood products.

Basic Formula

$$A \qquad R = \frac{3\ LS}{2\ WT^2}$$

where: R = modulus of rupture, psi
L = load to fracture test specimen, pounds
S = span, inches
W = width of test specimen, inches
T = thickness of test specimen, inches

This equation has five variables. Even though a slide rule can be constructed to include five different scales, this would not be the most practical solution to this particular problem. One of the variables, span *S*, can be taken care of by index points, which will be illustrated later. The use of index points is a simple method of taking care of a variable that has only a few fixed levels of magnitude.

Since width *w* varies inversely as the first power of modulus of rupture *R*, and since test specimens can be cut with ± 0.01 inch of a nominal 3 inch width, the formula can be further simplified by assuming a constant width. With *S* and *W* eliminated, the basic equation can be reduced from a five-variable to three-variable equation that can be expressed as follows:

$$B \qquad R = \frac{KL}{T^2} \text{ where } K = 0.5$$

The next step involves writing the simplified equation in logarithmic form as follows:

$$C \qquad \text{Log } R = \text{Log } 0.5 + \text{Log } L - 2 \text{ Log } T$$

Since the log of 0.5 is a constant, it can be taken care of by proper location of the index points, which obviates using it in the calculations; consequently, the basic equation can be expressed as:

$$D \qquad \text{Log } R = \text{Log } L - 2 \text{ Log } T$$

Range of Variables

Next, a decision must be made concerning the maximum and minimum limits of each variable. In the particular problem being illustrated, the following ranges were selected:

R (modulus of rupture): 3000 to 8000 psi
T (thickness): 0.090 to 0.400 inch
L (load): 10 to 450 pounds

Calculation of a "Modulus"

The modulus is a conversion factor dependent upon the length of the slide rule and logarithmic range of the variables involved. The spacing of scales in a slide rule is fixed; consequently, unlike on an alinement chart, the "modulus" must be the same for all variables.

After the length of slide rule and the ranges for the variables involved are decided upon, the "modulus" to use is determined by taking the variable with the greatest logarithmic range, in this case load. "Modulus" is then calculated as follows:

$$E \qquad M = \frac{D}{E \text{ Log } \frac{L_2}{L_1}}$$

Where D = assumed length of slide rule, 24 inches in this case
L_2 = maximum load or 450 pounds
L_1 = minimum load or 10 pounds
E = exponent or power of variable in the basic equation *A* with greatest logarithmic range, in this case E = 1

Then $$M = \frac{24}{\text{Log } \frac{450}{10}}$$

$$M = \frac{24}{\text{Log } 45}$$

$$M = \frac{24}{1.65321}$$

$$M = 14.52$$

To simplify laying out the scales, a modulus of 15 was used, which made the load scale slightly longer than 24 inches.

Format of Calculation Table

Table 1 illustrates, in an abbreviated form, the necessary calculations to determine the proper spacing for the subdivisions of the thickness scale on the slide rule. Only the minimum, maximum, and a few intermediate values are included in the table. Similar tables can be made up for load and modulus of rupture.

Table 1.—THICKNESS "T"

T x 1000[a] (1) Inches	Log T (2)	Log T—1.95424 (3)	Column 3 x 30 (4)[b] Inches
90	1.95424	0	0
130	2.11394	.15970	4.79
190	2.27875	.32451	9.74
252	2.40824	.45400	13.62
300	2.47712	.52288	15.69
400	2.60206	.64782	19.43

[a]Multiply by 1000 to simplify calculations by eliminating the decimal point.
[b]It is necessary to multiply by 30 instead of 15 because thickness varies as the second power with modulus of ruptue (see equation E factor "E").

Column 4 in Table 1 is the distance in inches from the minimum value to any other given value. A less time-consuming method of laying out the different scales on the rule involves obtaining or constructing logarithmic paper of the desired "modulus". With the aid of a pair of dividers, then measure the distance for a given value directly from the logarithmic paper and lay it off on the proper scale on the rule.

Construction of the Slide Rule

Three pieces of nominal 1-inch lumber, preferably hardwood, 1½ to 3 inches wide and of adequate length will serve well for the three scales. The two outer fixed scales should have a groove cut in one edge. The center movable scale should be machined with a tongue on each edge so it will slide freely between the two outer scales. The two outer scales should be secured to some backing material such as plywood, composition board, or wide piece of lumber (Fig. 1).

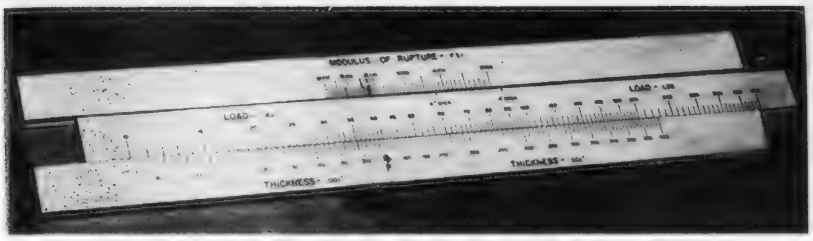

Fig. 1.—MOR slide rule in the Quality Control Department.

The most tedious and time consuming job is the marking off and lettering of each scale. It would be wise to obtain heavy-weight, smooth drawing paper on which to layout the scales. Center the scales to minimize the movement in calculation work. Once the initial point on a scale has been established, mark off very accurately each subdivision desired. Varying the lengths of the subdivision lines will facilitate reading. It may be wise to vary the magnitude or numerical value of the subdivisions from one end of the scale to the other. If this is not done, crowding or two wide a spacing of the subdivision lines may result. This is a matter of judgment and will depend upon length of the scale and accuracy desired.

After the paper scales have been subdivided and the major numerical values lettered onto the scales, each scale should be inked and given a durable protective film prior to gluing onto the previously prepared wooden scales. A simple alinement slide can be made by inking an etched line on a piece of heavy, clear plastic material. Such a slide will greatly facilitate reading the scales and lining up the desired numbers.

Location of Index Points

In the example of a slide rule for modulus of rupture, three of the five variables (R, T, and L) in the basic equation *A* have been accounted for on the three constructed scales. A fourth variable *W* can be a constant if the test specimens are accurately cut to a constant width. Handling the fifth variable span *S* will now be explained. This is done simply by assuming a given span *S* value, for example, 6 inches, taking any given thickness *T* and load *L* values and calculating the corresponding modulus of rupture *R*. Move center scale so the load and thickness line up. Immediately under the calculated modulus of rupture *R* value on the top fixed scale, place a rod indicating arrow on the adjacent edge of the center moving scale (Fig. 1). It is wise to repeat the same procedure using different load and thickness figures to be sure the indicating arrow or index point is accurate. Other index points can be located for any number of spans being used that will give *R* values within the limits of the scale. Fig. 1 illustrates two spans, the 4-inch and 6-inch.

Summary

The following steps are involved in constructing a practical slide rule to meet the essential requirements of time and accuracy in performing calculations in an effective quality control system.

Simplify the basic calculation equation, if possible, to eliminate variables. Express the simplified equation in logarithmic form. Make a decision concerning the length of slide rule to be built. Decide upon the minimum and maximum values for each variable to be included on the slide rule. Calculate a suitable "modulus". Compile calculation tables or obtain logarithmic paper with proper "modulus" for subdividing logarithmic scales. Build the scales from suitable material. Lay out the scales. Locate index points. Assemble and finish.

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7. Quality Control for Wet-Batch Hardboard

K. G. Borchgrevink

Hardboard Div., Evans Products Co., Corvallis, Ore.

Basically, the general objectives of statistical quality control are:

1. To check the quality within small limits of error by scientific sampling rather than by 100 per cent inspection.

2. To show clearly the progress in quality of production at any given time and over a period of time, and thus indicate where improvements are needed in raw materials, equipment, operating procedures, standard of manufacture, or personnel.

3. To indicate quality trends during manufacture, which from analysis and experience can be brought into control before they endanger the quality of a considerable amount of production.

4. To determine how much normal variation can be expected under the best reasonable operating conditions, and then to establish standards that can be held.

5. To stimulate quality-consciousness among personnel—with the record there for all to see—and thus produce a competitive quality spirit among employees.

Several requirements are necessary to make this or any other approach to quality control really work:

1. Establishment of consistent and adequate sampling, testing, and records to ensure reliable data, and with quality-control personnel adequately trained in the techniques of simple statistics and the realization that the variations are more important than the averages.

2. Establishment of standards of testing for the comparison of continuing production to the base—which may come not only from records, but other sources, such as commercial standards, federal specifications, and so forth.

3. Constant scrutiny of the operations in relation to the test results through constant observation and the use of adequate operations data sheets or automatic equipment records. This information is used to determine the capabilities of the men, materials, and equipment, and thereby gain an intimate knowledge of the process.

4. Whole-hearted cooperation of production supervisors and management in encouraging and enforcing a quality operation, rather than a hi-ball production, and their seeing that equipment is maintained for quality production. Also, thorough instruction of new operators and a tactful instruction of old ones as to what constitutes quality operation.

5. Consistently long runs on individual board types to gather data and hold control without excessive switching of types or "start-up" and the

consequent "leveling-out" of the process.

6. The control chart—adequately kept and well displayed. Proper sampling is fundamental to statistical quality control. It must be adequate for a complete picture, but yet practical from a business viewpoint.

Testing Methods

At the Evans Products Co. the chart is set up for the few most important physical test results only in an attempt to keep the system simple to handle and present it gradually to the plant personnel. It does not now include grading for appearance and surface, which is 100 per cent inspection. Constant weight and caliper inspection is done by sampling every other press load and charted separately. After the variations within press loads are determined, a representative board is selected.

Charted test data are limited to four properties, modulus of rupture, water-absorptions of 2 and 24 hours, and thickness caliper. Because most other properties, such as thickness swelling, wet strength, specific gravity, bond strength, and so forth, can be related to these few key properties, a good picture of over-all quality is presented. Other information is tabulated, however. For instance, 1/8-inch standard board is checked as shown:

1. Modulus of rupture—desired average of 6000 psi, upper and lower average limits of 6500 and 5500.
2. Water absorptions—2 hour desired average of 6 per cent, upper and lower average limits of 7½ and 4½ per cent.

   24-hour desired average of 17 per cent, upper and lower average limits of 20 and 14 per cent.
3. Thickness caliper—desired average of 0.135 inch, upper and lower limits of 0.145 and 0.125 inch.

Values were arrived at through statistical evaluation of past test data, together with knowledge of the plant's mechanical and personnel potential, best use and performance characteristics for customer satisfaction, competitor's tests, and the values from the federal specification for fibrous hardboards.

Boards made to special order for industrial customers may differ, of course, from these standards. Maximums for water absorptions and minimums for MOR and caliper were taken directly from the federal specifications.[1] Variation in control is limited to approximately two standard errors from each desired average. (All but 4.5 per cent normally expected to fall within control limits.) This fits quite well into the control requirements.

The testing for daily data is done as follows (when in control): a total of six test boards per day (two for each shift) are taken, one at the beginning of each shift and one from the middle. Test specimens are cut as follows from each board. (Fig. 1)

(a) for water absorption—3 pieces per board, one from 2 opposite edges and the center, all 3 by 12 inches.

(b) for MOR—6 pieces per board, 2 from each end and 2 from center, (all 3 by 12 inches), broken on an 8-inch span for ¼ and 3/16 inch, and on a 6 inch span for ⅛ inch.

(c) for caliper—the average caliper and range of the above nine pieces.

Note that the samples are not taken as required for the federal specifications, but the method selected is more efficient for routine testing, adaptable to the Evans operation, and assures that the boards will meet the specifications by giving a good picture of the board properties. The six simple boards per day result in a sampling percentage of only 0.3 per cent or so, but when the process is in control, this appears to be adequate statistically as well as practical from an economy and time standpoint. (The federal specifications also call for an 0.3 per cent sampling on large orders.) With "start-up", plant experiments, or "out-of-control" periods, this percentage is stepped up considerably.

An objection may be made to the taking of MOR specimens all in the cross direction. Evans has found, however, that with the wet batch process there is little or no significant directional orientation of fibers, and samples taken one way only give sufficient data. This simplifies cutting, and water absorption samples of this size may be used directly for wet-strength tests. The 3 by 12 soak sample gives a slightly higher value than do large, standard 12 by 12 pieces for an extra margin of safety.

The test results are analyzed and correlated with operating procedure, and changes are noted for any significant influence on results, especially long-range trends.

[1] Federal Specification LLL-H-35, Fibrous-Felted Hardboard.

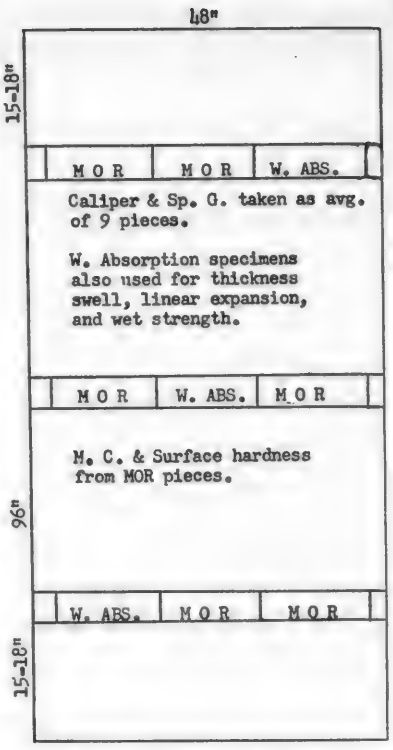


Fig. 1.—Cutting Diagram for Control Test Specimens.

Results and Conclusions

Certain results have become readily apparent from the charts. For instance, though average values are in general very acceptable, the variations have occasionally been somewhat greater than desired. With adequate control the variation is not abrupt, as from hour-to-hour or load-to-load, but shows a trend from shift-to-shift with operators, a more easily controlled type of variation. Referral to records and proper marking is helpful in selection of superior board for tempering and other specialties.

In addition to its present use for physical test data, the control chart could well be applied to specialized operations, such as trimming, punching, cut-up, and grading, but these are not now included.

In conclusion, with the statistical approach to quality control one can hope to better accomplish these aims:

1. Produce not only a high average quality board but control the variations from board-to-board and run-to-run.

2. Cut costs, principally by closer control of chemical usage when board begins to exceed the requirements, and increase efficiency.

3. Maintain and improve "quality consciousness" in operating and supervisory personnel.

4. Gather further data for "trouble-shooting" future problems and for re-evaluating present standards.

5. Produce as large a percentage of high-grade board as possible for highest net return to the mill per M feet produced.

Discussion

Anon.: How much time transpires between the time panels are made and the time when quality control results are made known? Do you attempt to assign quality control results to individual shipments?

Mr. Borchgrevink: To answer the second question first, yes, we do. Each package of board bears a code number indicating the time at which the board was made, and code numbers are shown on the invoices.

With respect to the question about time, samples are taken from board directly after hot pressing and also after humidification. The results of MOR tests are made known to the foreman and superintendent immediately and results of the 2-hour water soak are known shortly thereafter. These results are confirmed later by the laboratory tests. We actually take tests of the hot, dry board right from the hot-press, as well as board that has been humidified, and find considerable differences at times. We have to try to correlate the two different types of tests.

General Discussion

Mr. G. E. Tower: What consideration has been given to the use of non-destructive tests? I know some of our tests are non-destructive, but I am wondering if any of our panel members have thought along that line?

Mr. Bryant: From an academic point of view, we have done a little work testing E of particle board non-destructively. It is possible to make measurements of E on particle board by stopping short of the proportional limit during the test. Having E, one can study the effect of various facings on this type of particle board, for example.

Mr. Runckel: It might be desirable to weigh and caliper every board as it comes from the press, if it does any good to do so.

Mr. Tower: Those tests are used and they are non-destructive. One of the important ones—MOR—requires using up part of the board.

Mr. A. L. Mottet: Have any of the panel members done work in determining wet strength of boards for use in quality control? Long-Bell Company has performed flexure tests on boards dry and following 24 hours of soaking.

Mr. Runckel: As far as using it from the customer's standpoint, we have found no use at all for it.

Mr. Borchgrevink: We have run a considerable number of these tests on our board, principally because the Hardboard Association was considering it for their specifications, to see if our board fitted in with the specifications. We found to our satisfaction that it would. We do not run the test as a regular quality control test, but every now and then we check it.

Mr. Harold Ely: Mr. Johnson, I believe you said all boards, regardless of whether tempered or standard, came to the same final equilibrium moisture content in the humidity test. In other words, going back to Dr. Clark's statement, the baking did not seem to change the hygroscopic nature of the wood. Is that the conclusion you draw?

Mr. Johnson: Please refer to Table 4, Column 6, of the original report. Notice that at the end of eight months, all the hardboards, regardless of treatment, were at approximately the same moisture content. That is, they had absorbed about the same amount of water (roughly 11 or 12 per cent), and remember that all had started out with about the same moisture content. Also, notice in Column 9 that after ten days most of the boards had absorbed between 85 and 90 per cent of the water that they eventually absorbed in eight months. In other words, in ten days' time the moisture content was not greatly different in all the hardboards. Some measure of this difference can be seen in Column 4 of Table 4.

Mr. Ely: Most panel speakers have limited their remarks to specifications and testing. Have they tried to apply typical quality control to a particular part of the plant, such as at the pulper or at the press, to see if that phase is in control?

Mr. Runckel: Basically, variations in raw material cause a considerable number of problems, and all of us are working on this problem all the time irrespective of the type of process. At the wet-end, the wet-machine is an important step to control. In fact, every machine is important and has to be checked; every piece of equipment is tied in to the control process.

Mr. Ely: Do you do it statistically then?

Mr. Runckel: Yes. Very definitely!

Mr. Stillinger: You have hit on an excellent point. It seems to me desirable to have adequate sampling along the line before you get material out of the press. My approach has been to check the moisture content data and the bulk density data with adequate sampling and statistical analysis; the other end, finished product variability, pretty well takes care of itself. I think this is a much sounder approach than letting come out what will, then analyzing the product to see what the variations are, and then going back through the maze of variables to try to find what caused that extreme variation. Unless we know the variation of the various components, we are not in a very good position to analyze the product variability and decide what is the most likely thing that went wrong, until we get some idea of the relative magnitude of the variation that can be caused by various process variables.

Mr. Isaacson: If you don't control the process there is not much use in controlling the finished board. Actually, you will know what you are making but if it isn't any good you've lost it. In particle board, resin plays a most important part and to reduce resin content as much as possible, and still maintain specifications, is a goal everyone is working for. We have a statistical chart set up for resin usage alone, and if it strays from the average we immediately watch it and we'll know if there is anything wrong with the pumps. The same thing goes for the dryer. Drying is, of course, an important part of any synthetic board manufacturing process.

Abstracts From Current World Literature

Gluing

Myers, J. Further developments of the 'Stray Field' platen. *Timber Technology,* Vol. 66, No. 2226, April 1958, pp. 178–9

High-frequency heating techniques have become more popular in the furniture industry for setting ureaformaldehyde resins because of the rapidity of the method. Most high-frequency generators in the furniture industry are coupled to sub-assembly jigs, constructed on the 'glue line' heating principle, which requires a high degree of accuracy in their manufacture. With the stray field platen technique it is possible to design a jig for flat panel work large enough to cover a wardrobe end panel. It simplifies jig construction and makes it possible for the small manufacturer to utilize high-frequency heating equipment as no specialized jig maker is required.

A total glue spread of 2 sq ft can be cured in 1½ min with a 3kW generator. Doubling the power would halve the curing time. The setting time, or power requirements, depends entirely on how long it takes to load a jig, no advantage being gained by using equipment capable of setting glue in 30 seconds if the jig takes a minute or more to load. Modern furniture designs and radio cabinets lend themselves to this method of high-frequency heating. [F.D.C. Tech. Bul. V. 7, No. 40]

Preservation

Merrick, G. D. Wood Preservation Statistics, 1956. American Wood Preservers' Assn., 839–17th St., N.W., Washington 6, D. C., Sept. 1957, 34 pp, free

Statistics compiled by Mr. Merrick of U. S. Forest Service represent the output of 325 wood-preserving plants of which 229 are pressure-treating plants, 73 non-pressure and 23 equipped for both processes. Report deals with cross arms, fence posts, piles, poles, lumber and timbers treated; has regional breakdowns, lists preservatives used, etc. [BRI Abstracts, June 1958]

Zabel, Robert A., and O'Neil, Frederic W. The toxicity of arsenical compounds to microorganisms. *Tappi* 40, no. 11: 911–14 (Nov., 1957).

The relative toxicities of 44 arsenicals to four common slime-forming micro-organisms—*Aerobacter aerogenes, Bacillus mycoides, Aspergillus niger,* and *Penicillium expansum*—were evaluated by the Petri-plate method. Organic arsenicals, such as 8-hydroxyquinoline arsanilate, 8-hydroxyquinoline methyl arsonate, and silver cacodylate, demonstrated considerable bactericidal and fungicidal activity within the concentration ranges of some commercial slimicides. The relationships between chemical structure and toxicity are discussed. The addition of an arsenical to the 8-hydroxyquinoline molecule appears to increase toxicity. In many compounds, toxicity appeared to be independent of the amount of arsenic in the molecule. The toxicity of several organic arsenicals suggests a more comprehensive search of these compounds for potentially effective toxicants for use as wood preservatives, insecticides, slimicides, and herbicides. [Bul. Pap. Chem. V. 28, No. 5]

Finishing

Blount, Ezra A. A Survey of Paint Application Methods. *Products Finishing,* Gardner Publications, Inc., 431 Main Street, Cincinnati 2, Ohio, 1957, 59 pp, 50¢

Booklet contains assembled reprints of a series of articles run in March, April, June, August and December 1957 in the above-named magazine. Data are presented on paint application by: spray gun; conveyorized spray finishing, automatic spraying, electrostatic spraying; hot spray, airless spraying, steam spraying, spraying catalyst coatings; dipping methods, flow coating; roller coating, tumble and centrifugal painting, silk screening and aerosol painting. There is a table showing spray painting troubles and remedies, and the booklet is well illustrated. [BRI Abstracts, June 1958]

Pathology

Struble, George R. The fir engraver. U. S. Dept. Agr., Forest Serv., Calif. Forest and Range Exp. Sta., Production Research Rept. No. 11, Washington, U. S. Govt. Print. Off., 1957. 18p.

The fir engraver *(Scolytus ventralis* Lec.) is a major enemy of white fir, red fir, and other true firs *(Abies),* as well as of Douglas-fir, Engelmann spruce, and mountain hemlock in western forests. This bark beetle attacks trees from pole size to mature timber. Some trees are killed in a single season, others are top killed, and often there is severe branch killing. Many trees, weakened through successive attacks, die slowly over a period of years. Even though they survive the injury, partially attacked trees may develop defects and rots which render them unfit for commercial use. Promising insecticides include toxic oil sprays containing either ethylene dibromide or 1,2-dichlorobenzene. The hosts, distribution, life history, and habits of the beetle, character of damage, associated insects, and control methods are described [Bul. Pap. Chem. V. 28, No. 5]

Construction

Trends in Utilization of Wood and Its Products in Housing. Information Liaison Office, Room 372, United Nations, New York 17, N. Y., 1957, 49 pp, 50¢

A study prepared jointly by the Food and Agriculture Organization of the U. N. and the United Nations Economic Commission for Europe. Deals with the uses of wood in new residential construction in an effort to throw light on future trends in sawnwood consumption. Noted is the decline of the all-wood house and the progress of prefabrication in European countries. Special chapters deal with joinery, formwood and scaffolding, and other wood materials used. Data have been assembled into a large number of informative tables to supplement the text. [BRI Abstracts, June 1958]

Particleboard

Bottcher and Gessner, Germany. Automatic finishing for chipboard.

This equipment is a completely automatic set-up for four-sided trimming, two-sided sanding, and stack-piling of chipboard panels. The panels straight from the press are piled carefully on wooden racks and from then on a machine takes over. It consists essentially of a metal-searching device, automatic four-sided trim saw, a four-drum or three-drum sander for top surfaces, a drum sander for bottom surfaces, a panel turning device for inspection of both sides, and selection into first or second grade. All these machines are fed automatically and linked to each other by a series of hoists and conveyors, with the panels finally being stacked in two separate grades as directed by the inspector. The feed speeds of the various machines are adjusted so that any jumping is avoided, and should one motor fail, automatic switching ensures the stoppage of all the others. The maximum size of panels which can be handled is approximately 129 × 57 in. [F.D.C. Tech. Bul. V. 7, No. 40]

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BRI ABSTRACTS OF BUILDING SCIENCE PUBLICATIONS, published for the use of its members, by the Building Research Institute, National Academy of Sciences—National Research Council, 2101 Constitution Avenue, Washington 25, D. C. Over 70 periodicals are reviewed, plus new books and research reports from industrial, governmental, and academic laboratories and organizations.

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiberboard and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

Around the World in Forest Products Research and Development

A Russian's Theory on

The Strain Behavior of Wood

PROF. YU. M. IVANOV

Institute of Forests, Academie of Sciences of the USSR, Moscow

This discussion was prompted by and refers to a previous article in the *Forest Products Journal* (King, E. G. 1957. FPJ, VII (10): 324). Such contributions from around the world, on either fundamental or applied subjects, are sincerely appreciated.

THE ARTICLE BY KING describes interesting work carried out with elaborate procedure and an ample program. The study of the creep of wood in tension parallel to the grain, which is difficult experimentally, had not previously been done in such detail.

It is interesting to note that King's data for basswood, cedro branco, and angelique are, in general, consistent with the results obtained by us for European pine (*Pinus silvestris* L). In particular can be mentioned a divergence of strain behavior of wood from Hooke's law or nonlinear diagram $\sigma - \epsilon$, for the initial part of which from 0 up to σ_{pf}[1] we suggested an equation of the second order. King had cited two of our works, of 1938 and 1949, but since that time there were obtained some new data that should be added to that mentioned.

The results obtained recently by us reaffirmed that wood has two regions of deformation. The boundary between these regions, called primarily the limit of plastic flow σ_{pf}, has quite definite physical meaning. At the same time, σ_{pf} depends on the rate of loading. Curves in Fig. 1 indicate that σ_{pf} in compression parallel to the grain, as well as ultimate strength σ_{us}, increases with the rate of loading[2] (a—air-dry and b—wet pine wood).

To extend the time of load action, specimens were tested in step-wise fashion with duration of each stress station up to three or more days. These tests in bending indicated a progressive diminishing of σ_{pf} as well σ_{us}. Therefore, the short-term value of σ_{pf} is higher than long-term strength σ_{1s} of wood, and a coincidence of σ_{pf} and σ_{1s}, primarily assumed by us, was not confirmed. It might be more probable to suppose that both σ_{pf} and σ_{us} tend after a very long period of load action to coincide with the same value, σ_{1s}.

Fig. 1.

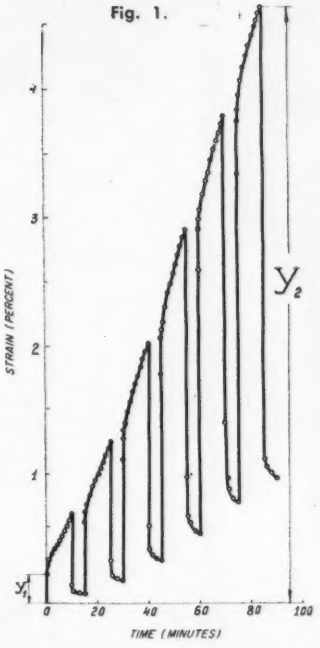
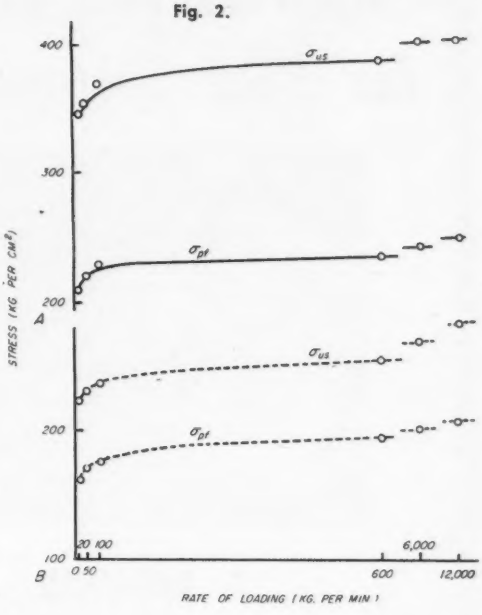


Fig. 2.



Further investigations on creep of wood showed that a residual strain in compression parallel to the grain beyond σ_{pf} was almost completely recovered on subsequent swelling of air-dry wood or heating wet wood in water. Thus, the residual strain in the second region of deformation of wood, earlier conceived by mistake as permanent set, is in reality a retarded moisture- and thermo-reversible deformation.

In general, the residual strain of wood should be considered in direct connection with elastic strain—that it develops with time. As it is known, such a strain of relaxation nature is inherent to high polymers.[3] The conclusion made by King of a causal relation between creep and set is consistent with this view.

Also obtained was proof that a more striking similarity exists between strain behavior of wood and that of polymers. A highly elastic deformation was disclosed in swollen wood at the stress level beyond σ_{pf} in compression parallel to the grain.[4] This deformation (Fig. 2) reached a value up to 4 or 5 per cent of initial length (in other experiments even up to 10 per cent), and had all the main features that characterize the strain of polymers in a highly elastic state.

The analysis of these facts led us to the conclusion that high elasticity in swollen wood beyond σ_{pf} occurs due to distortion of bonds of molecules of cellulose. The gradual rise of mobility of chains of cellulose under sustained load, that is, in the process of development of isothermal strain, begins down from the moment of exceeding σ_{pf}, as result of reduction of the potential barrier of bond distortion in the stress field. The stress σ_{pf}, therefore, which may be termed here as the beginning of high elasticity, cannot be a constant one, but must decrease with duration of force as shown by experiment. There is a distinction between the strain behavior of wood and that of high polymers, but it is not possible to dwell on it in this brief note.

In conclusion I would like to say with confidence that further investigations on creep phenomenon in wood, which will be carried out in several countries at different aspect, will undoubtedly draw us to a better understanding of the strain behavior of wood in all its complications as well as of the related long-term strength.

[1] The limit of plastic flow.

[2] See our article, 1953 Trudy Instituta Lesa, Academie of Sci. of USSR, v. 9, p. 431.

[3] H. Mark. 1945, Amer. J. of Physics, 13:207.

[4] Yu. M. Ivanov. Doklady Akademii Nauk SSSR, 1956, 111, N 4, 777–779; Composite Wood, 1957, 4 N 4, 51–53; Kolloidnyi Zurnal, 1957, 19, n 3, 293–298.

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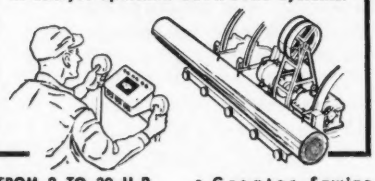

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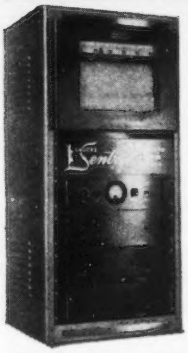

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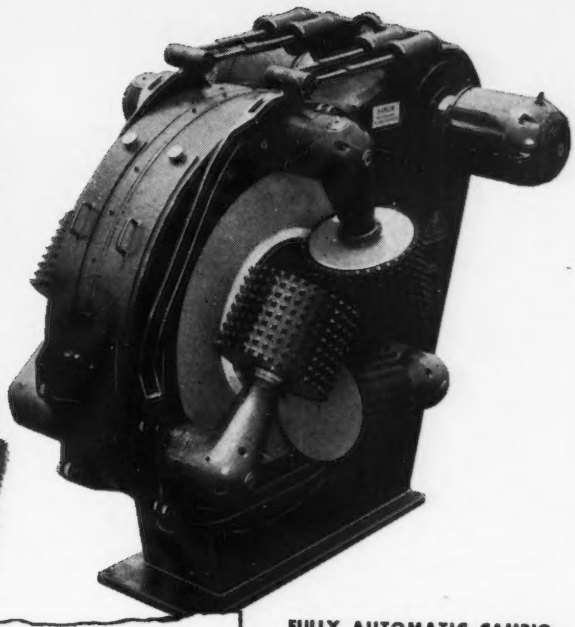
Thank you Mr. Allen!



We recently received this unsolicited letter — quoted in part below — from Mr. C. D. Allen, President, Allen-Peavy Lumber Co., Kountze, Texas.

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KOUNTZE, TEXAS

June 5, 1958

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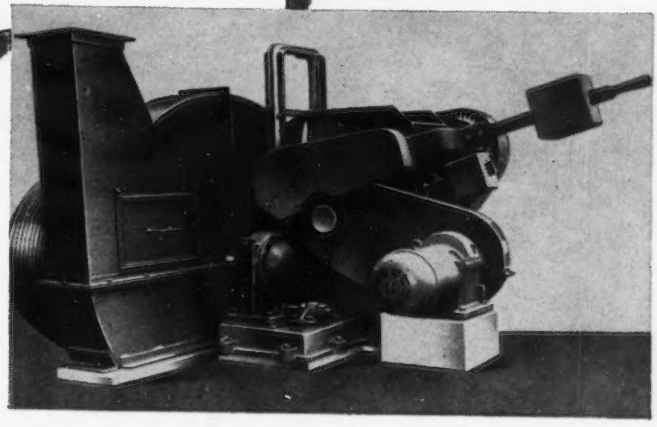

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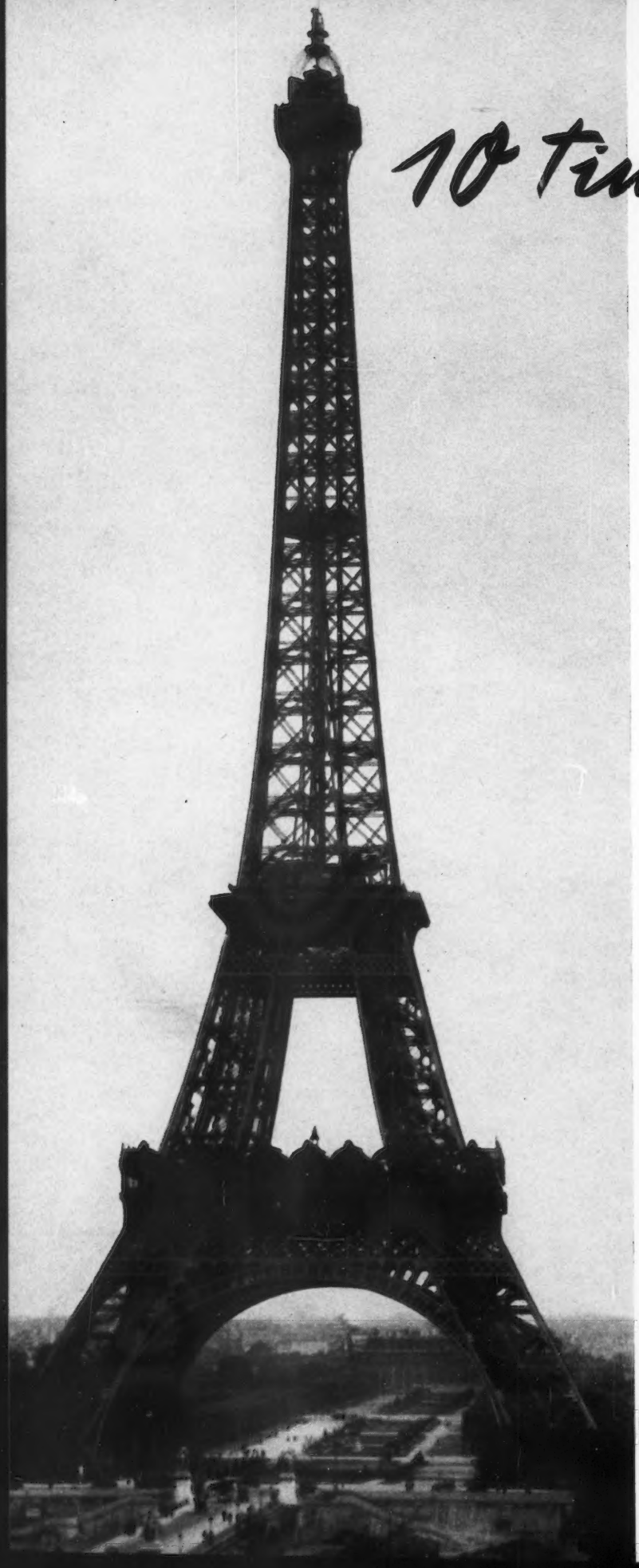

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